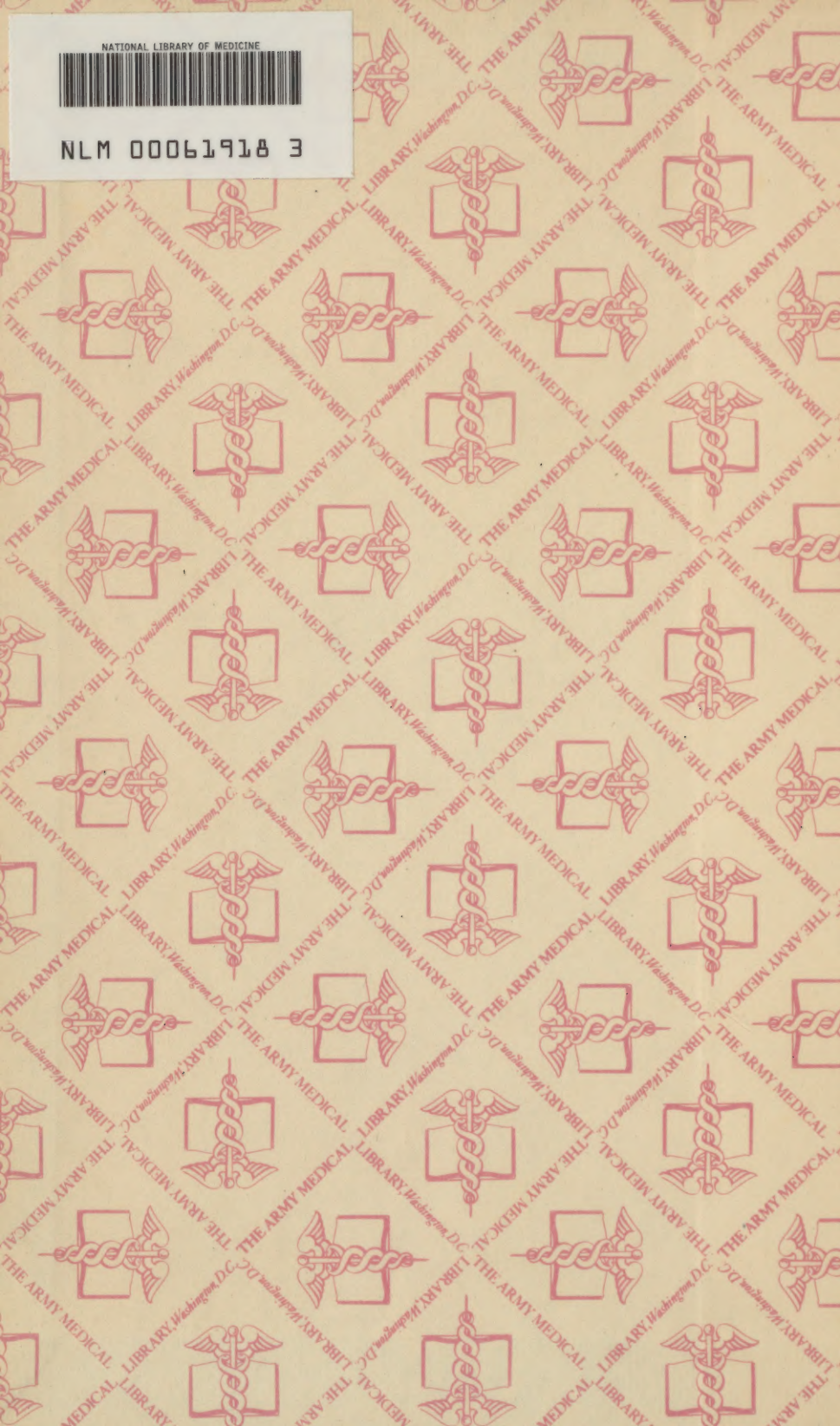


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MILITARY WATER SUPPLY AND PURIFICATION



WAR DEPARTMENT •

AUGUST 1945

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WAR DEPARTMENT
Washington 25, D. C., 22 August 1945

TM 5-295, Military Water Supply and Purification, is published for the information and guidance of all concerned.

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BY ORDER OF THE SECRETARY OF WAR:

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Refer to FM 21-6 for explanation of distribution formula.

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CHAPTER 1

INTRODUCTION

1. Purpose and Scope

This Technical Manual covers water purification. It discusses the impurities which make water unsafe to drink and tells how to remove them. It describes military water purification equipment and tells how to use it. Finally, it covers the installation and operation of water points.

a. This manual is written primarily for military personnel responsible for operating water purification equipment. Any persons requiring more technical information should refer to the manuals listed in paragraph 4 or to the reference books listed in appendix III.

b. For operation and maintenance of water purification equipment, see the Technical Manual which comes with each major item of equipment. (See FM 21-6.).

2. Water Problem

a. **IMPORTANCE.** Tactical missions cannot succeed unless troops have *enough safe water*. Water is even more important than food. In extreme heat or when severely exerted, lack of water may put a soldier out of action within a day. Untreated or improperly treated water almost always contains enough disease germs to make it dangerous to drink. The health of the entire command is in the hands of the water purification equipment operators. They must know their job and do it right.

b. **QUANTITY.** The amount of water required for troops in camps and hospitals in theaters of operations are given in TM 5-280. The daily amount of water required by each soldier in combat, on the march, or in bivouac are given in table I.

c. **QUALITY.** Drinking water must be free of disease-producing organisms, poisonous chemicals, and objectionable color, odor, or taste. All untreated water is considered unsafe until approved by a medical officer.

d. **SOURCES.** When water is readily available in an area and all sources are free of unusual impurities, the following rules should guide in selecting the source.

(1) In populated areas, use established public systems to the fullest extent. (See ch. 6 for details.)

(2) Use existing springs or wells next. The quality of water from these sources is usually better than from surface sources.

(3) If public or ground-water sources are not readily available, use surface-water sources such as rivers, streams, lakes, or ponds.

(4) When other sources are not available, dig wells to use ground-water sources. Development of new ground-water sources is not practical for an army on the move. For rear-echelon units, a ground water source is usually best, especially in areas where surface-water sources are highly contaminated as in China, the Philippines, India, Japan, and other parts of Asia.

Table I. Quantities of water required per man per day for troops

| Condition | Gallons per day | Remarks |
|------------------|-----------------|--|
| Combat | ½ (min) | Absolute minimum for not longer than 3 days. Used for drinking. Some allowance for cooking and personal hygiene. |
| | 1 | |
| March or bivouac | 2 (min) | Enough for drinking and cooking, washing of mess and kitchen utensils, washing hands and face. |
| | 5 | |
| Temporary camps | 5 (min) | Should be supplied if possible; will permit some bathing and laundry. |
| | 15 (min) | Does not include bathing or sewage facilities. |
| | 15 (min) | Includes bathing. Permits water-borne sewage. |

(5) As a last resort, when no fresh water source can be found, use distillation units to purify sea water.

3. Responsibilities

Responsibility for water in the Army is shared by the unit commander (customer), the Corps of Engineers (supplier), and the Medical Department (inspector). Detailed responsibilities are listed below.

a. UNIT COMMANDER. The unit commander is responsible that all units and individuals of his command have the required amount of safe drinking water at all times. He must make clear to every individual the danger in drinking unsafe water. He must enforce strict water discipline. Water discipline rules are:

- (1) Drink treated or approved water only.
- (2) Don't waste purified water.
- (3) Protect sources of water by good sanitary habits.

b. CORPS OF ENGINEERS. The Corps of Engineers is responsible

for making available a supply of treated water for all purposes to all Army units. It is responsible for the design, procurement, installation, operation, and maintenance of water supply equipment. In addition, it makes reconnaissance, develops sources, and transports water to distribution points. It works closely with the Medical Department to make certain the water is safe to use.

c. MEDICAL DEPARTMENT. The Medical Department is responsible for determining whether or not water is safe and for making recommendations to proper authorities. To do this, the Medical Department inspects water points and sources, tests water, and in general works closely with the Corps of Engineers to insure that water is properly treated and distributed. In addition, the Medical Department studies and makes recommendations about the design and selection of water purification equipment.

4. References

The following manuals contain information about water supply:

| | |
|--|-----------|
| Engineer Troops and Operations | FM 5-5 |
| Camouflage: | |
| Basic Principles | FM 5-20 |
| Of Vehicles | 5-20B |
| Of Bivouacs, Command Posts, Supply Points, and Medical Installations | 5-20C |
| Of Rear Areas and Fixed Fortifications | 5-20G |
| Materials and Manufacturing Techniques | 5-20H |
| Reference Data | FM 5-35 |
| Staff Officers' Field Manual, The Staff and Combat Orders | FM 101-5 |
| Staff Officers' Field Manual, Organization, Technical and Logistical Data | FM 101-10 |
| Military Sanitation | FM 21-10 |
| Construction in the Theaters of Operations | TM 5-280 |
| Ground-water Supply for Military Operations | TM 5-296 |
| Well drilling | TM 5-297 |

Note. Technical Manuals on operation and maintenance of water purification equipment. Two copies are issued with each item of equipment. If lost, see FM 21-6 for number and title.

Army Service Forces, Supply Catalog, ENG 2.

CHAPTER 2

WATER QUALITY

Section I. INTRODUCTION

5. General

a. Water is never absolutely pure. Impurities vary from dissolved gases, chemicals, and minerals to suspended matter like disease germs and dirt. Some can be seen, some cannot be seen but can be detected by taste or odor, and others can be detected by laboratory tests only. This chapter covers the impurities in water, how they got there, and their effect on the water and on the human body.

b. Safe water is free of disease-producing organisms, poisons, and excessive amounts of mineral or organic matter. Military drinking, cooking, and washing water must be safe. In addition, when time and equipment permit, the water should be clear, free of objectionable tastes and odors, and cool.

6. Useful Words

a. Water purification equipment operators need to know the meaning of some technical words used in water supply work.

b. When water contains harmful impurities, it is called contaminated or polluted. *Contaminated* water contains germs or other substances which make it unfit for use. *Polluted* water contains substances which give it an objectionable appearance, taste, or odor.

c. Contaminated water is unsafe but the impurities in it usually cannot be detected by sight, taste, or smell. Polluted water on the other hand is easily detected. Generally polluted water is also contaminated.

d. Water is also described as *potable*, that is both safe and drinkable; and as *palatable*, pleasing to drink. Palatable water, however, is not always safe.

e. Other useful words are defined throughout the manual and all definitions are collected in a glossary in appendix IV.

7. Sources of Impurities

a. Water gathers impurities as it goes through its natural cycle. (See fig. 1.) It first picks up the organisms, dust, smoke, and gases which fill the air through which rain, snow, hail and sleet fall. Rain water, then, is not pure, although it is relatively free of dissolved minerals.

b. Water flowing over the earth's surface picks up dirt, disease organisms, chemicals, and anything else in its path which can be dissolved or moved. Water which soaks into the ground loses many of its suspended impurities as it filters through the earth. However, although it becomes clearer, it dissolves minerals and other chemicals at the same time. Ground water, then, may be clear, but it is not pure and may contain harmful disease organisms as well as chemicals.

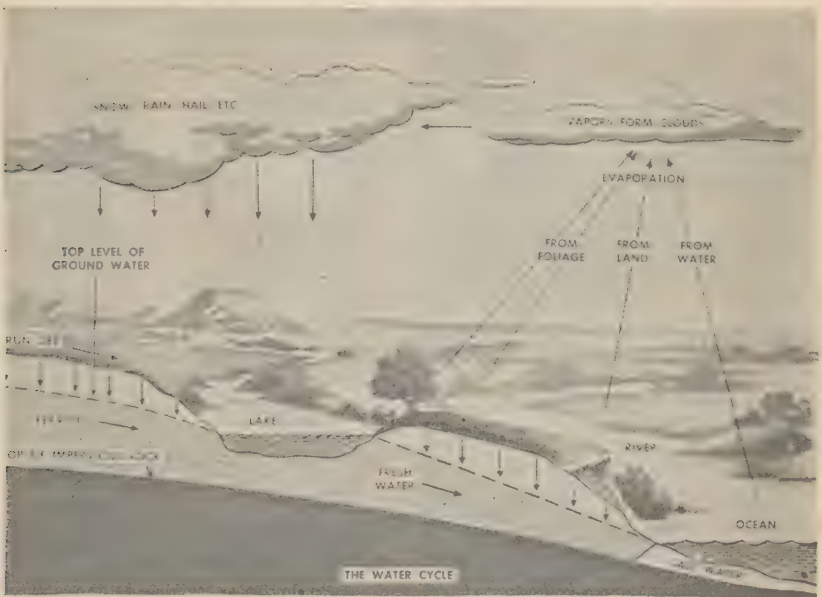


Figure 1. The water cycle.

8. Types of Impurities

All impurities in water are either suspended or dissolved. Each of these main classes can be further divided as shown in table 2. Suspended impurities are usually more dangerous to health than dissolved impurities. The suspended impurities consist of mineral matter such as sand, silt, or clay, of disease organisms such as bacteria or protozoa, and of water plants such as algae. It is absolutely necessary to remove or destroy the disease-producing organisms in water to be consumed by troops.

Table II. Common impurities in water

| | | | | |
|----------------------|------------------|--|---|--------------------------------------|
| SUSPENDED IMPURITIES | Organisms | Some cause disease | | |
| | Algae | Cause taste, odor, color, turbidity | | |
| | Suspended solids | Cause murkiness or turbidity | | |
| DISSOLVED IMPURITIES | SALTS | Calcium and Magnesium | Bicarbonate | Causes alkalinity, hardness |
| | | | Carbonate | Causes alkalinity, hardness |
| | | | Sulfate | Causes hardness |
| | | | Chloride | Causes hardness corrosive to boilers |
| | | Sodium | Bicarbonate | Causes alkalinity |
| | | | Carbonate | Causes alkalinity |
| | | | Sulfate | Causes foaming in steam boilers |
| | | | Fluoride | Causes mottled enamel of teeth |
| | | | Chloride | Causes salty taste |
| | IRON | Causes taste, red water, corrosive to metals | | |
| | MANGANESE | Causes black or brown water | | |
| | VEGETABLE DYES | Causes color, acidity | | |
| | GASES | Oxygen | Corrosive to metals | |
| | | Carbon dioxide | Causes acidity, corrosive to metal | |
| | | Hydrogen sulfide | Causes odor, acidity, corrosive to metals | |
| | | Nitrogen | No effect | |

Section II. WATER-BORNE DISEASES

9. General

a. Figure 2 shows the general factors in the spread and control of intestinal diseases. Note that water carries many of the organisms that produce these diseases. Disease-producing organisms carried by water fall into two classes: those readily destroyed by chlorination, and those that are chlorine-resistant. Although the chlorine-resistant organisms require careful treatment, they can be destroyed by the purification methods given in chapter 3.

b. It is important to understand that water-borne diseases do not appear immediately after drinking contaminated water. Disease-producing organisms need time to grow and multiply inside a man before they make him sick. The time between drinking contaminated water and the appearance of the disease is called the incubation

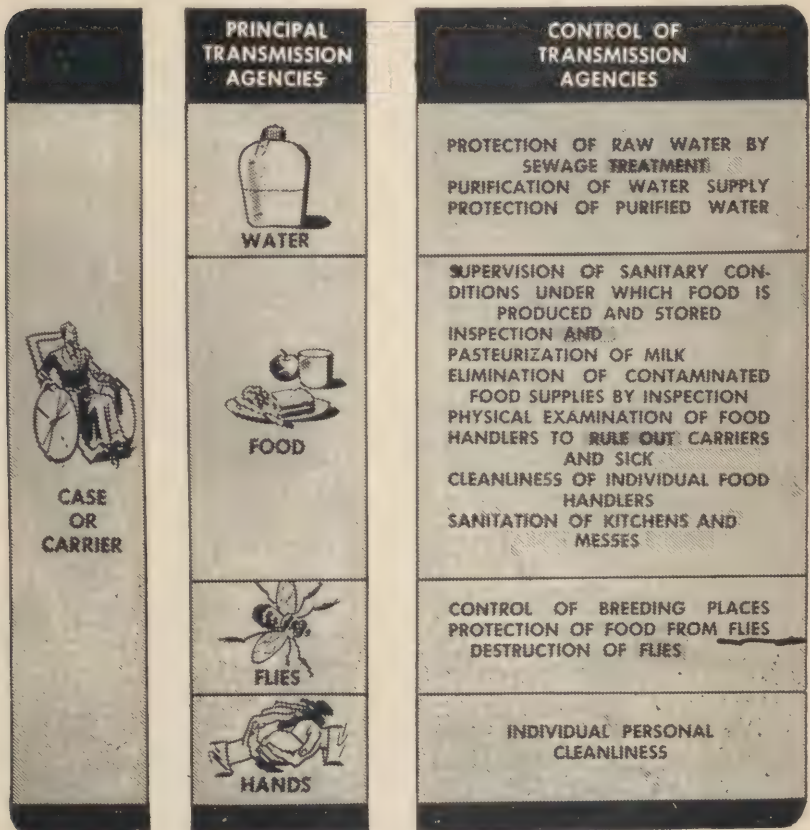


Figure 2. General factors in the spread and control of intestinal diseases.

period. Absence of disease symptoms for several days after drinking untreated water is, therefore, no guarantee that the water is pure. Lack of disease symptoms in natives is no test either, as they may have become immune.

10. Typhoid Fever

a. Typhoid fever is an intestinal disease which causes a rose-colored eruption of the skin, a high fever lasting about 4 weeks, and frequent bowel movements. It is caused by a water-borne bacteria (*bacillus typhosus*) which is readily destroyed by standard field chlorination. (See par. 41.) The incubation period before the disease appears varies from 3 to 40 days, average time being 7 to 10 days. Recovery from an attack of typhoid fever usually gives permanent immunity, although second attacks sometimes occur. The vaccination given every soldier gives him considerable protection, but it may be overcome by drinking highly contaminated water.

b. The disease organisms are transferred in the feces discharged from the body in bowel movements. This waste matter contaminates any water flowing over it. The disease organisms do not multiply in the water, and most of them die within a week. The colder the water, the longer the organisms live. In ice, they may live 3 months.

11. Paratyphoid Fever

Paratyphoid fevers are very much like typhoid fever in method of infection and symptoms. A man is made immune by vaccination or by recovering from an attack of the disease. However, a man immune to paratyphoid fever is not safe from typhoid fever, and an attack of typhoid does not give immunity to paratyphoid. The incubation period of paratyphoid fevers is 4 to 10 days, averaging about 7 days. The organisms are readily destroyed by standard field chlorination methods.

12. Cholera

a. Cholera is an infectious intestinal disease which causes violent vomiting, cramps, emptying of the bowels, and rapid collapse with subnormal temperature. Contaminated water is a frequent method of spreading the disease, and is probably the chief cause of severe epidemics. In addition to water, cholera is spread by food and contact. The organism is readily destroyed in water by standard field chlorination methods.

b. The organisms are discharged from the body in the feces where they live for several days. If water contacts this waste, the

organisms are carried along with the water where they may live for several weeks and under favorable conditions may actually multiply. The incubation period is usually about 3 days, although this particular disease may strike within a few hours after drinking contaminated water. About half of all people who get the disease die from it. Recovery from the disease produces some immunity but it does not last very long. Vaccination gives temporary immunity, but sanitary measures provide the only certain protection. Cholera occurs in the Philippine Islands, India, and in other parts of Asia.

13. Bacillary Dysentery

Bacillary dysentery is an infectious intestinal disease which causes frequent bloody, mucous-filled bowel movements. It usually occurs under the same bad sanitary conditions that bring on typhoid fever. The disease-producing organism is a bacteria (called "*Bacillus shigella*") readily destroyed by standard field chlorination methods. The incubation period is usually 2 to 3 days. The organism resists cold and will live in soil or on clothing for many days. It is found in tropical and subtropical areas.

14. Amoebic Dysentery

a. Amoebic dysentery is an infectious intestinal disease which resembles bacillary dysentery in many of its symptoms but which is caused by the disease organism called "*Endamoeba histolytica*." This organism is a very small animal rather than a bacteria, and it resists ordinary chlorination. Amoebic dysentery is primarily a disease of the tropical and subtropical regions, but it is also widespread in the temperate zones. The incubation period varies from 10 days to several months.

b. The disease is carried by cysts of the amoeba which form in the intestines of an infected person and are discharged in bowel movements. A cyst is a shell or sac which surrounds the amoeba. Drying destroys the cyst form of the organism in a few minutes. In water, the cysts may live from several days to several weeks.

c. Amoebic dysentery cysts can be removed from water by proper treatment or can be destroyed by chlorination. Water containing amoebic cysts must be properly treated because the cure for the disease is long and difficult.

15. Schistosomiasis

a. Schistosomiasis (shis'-toe-so-my'-ah-sis) is a disease caused by a small worm (schistosome) entering the body either through the skin while bathing, swimming, or washing in the contaminated water, or by drinking the water. These disease organisms are some-

times called blood flukes. The disease is tropical or subtropical and occurs principally in China, the Philippines, Japan, Africa, northern South America, and certain of the West Indies. It may be present on any islands held by the Japanese. See figure 3 for distribution of the disease.

b. There are three types of schistosomes. The incubation period for all types is several months. One type, *Schistosoma haematobium*, found principally in Africa, attacks the bladder and causes blood in the urine. The second type, *Schistosoma mansoni* found in northern South America and Africa, attacks the lower intestines and causes an ulcerated condition of the rectum. The third type, *Schistosoma japonicum*, found principally in Japan and China affects the large intestine and also causes painful enlargement of the liver and spleen. This last organism is sometimes called a liver fluke.

c. All types of schistosomes have a similar complicated life cycle. Eggs of the parasite are eliminated from the infected person in the urine or feces. In fresh water, the eggs hatch into very small free-swimming larva which cannot infect the human body. Before these larva can become infectious to humans, they must find fresh-water snails inside of which they change into the next form, called cercariae. If the larva do not enter a snail within 24 hours of hatching, they die. Therefore, if all snails are killed in the water source, the schistosome cycle stops. As cercariae, they are highly infectious to human beings, since they can go through the skin. However, the cercariae can live only 36 hours in water. Therefore, snail-free water which has been stored more than 36 hours is safe. These cercariae can be destroyed by chlorination. (See par. 48.) Water highly contaminated with schistosomes can be detected by its milky turbid appearance.

16. Common Diarrhea

Diarrhea is the name given to a number of intestinal diseases which cause cramps and frequent emptying of the bowels. The feces are usually watery. Diarrheal diseases generally occur whenever sanitary protection of food and water is inadequate. Where the infecting organisms are spread by food, the disease is restricted to the consumers of the contaminated food. Water-borne epidemics are usually more wide-spread, and in the absence of proper control measures, last longer. Many mild cases of more serious intestinal diseases are reported as common diarrhea.

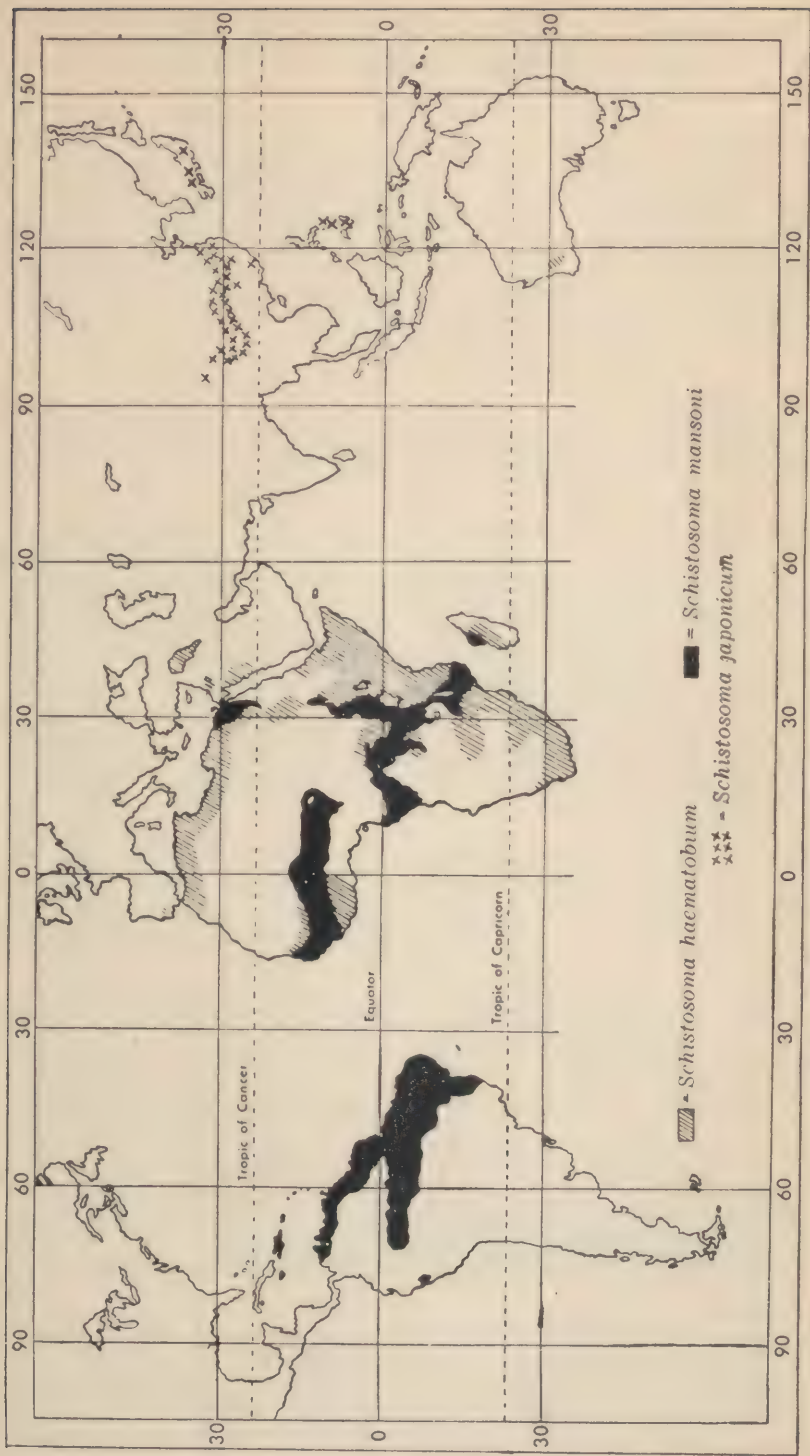


Figure 3. Geographical distribution of three types of schistosomes.

Section III. CHARACTERISTICS OF WATER

17. General

Water takes on various characteristics or properties depending on the substances which it meets. These characteristics and properties include turbidity, color, taste, odor, pH value, and dissolved gaseous and mineral substances. This chapter discusses these characteristics and their causes. For methods of overcoming objectionable characteristics, consult chapter 3.

18. Turbidity

a. Turbidity is a muddy or unclear condition of water which is caused by suspended material. Water running over soil picks up small bits of dirt and carries them in suspension. The faster the water flows the more material it picks up and the larger the size of the pieces carried along. This suspended material varies from sand, silt, and clay to organic material like decaying vegetation and animal wastes. When water containing suspended material slows down, the larger particles settle out. As the velocity of flow continues to decrease, smaller particles settle out. When the flow of water stops, all but the finest particles settle out. Clay remains suspended in water longer than any other material because it has the smallest-sized particles. It may take months for all clay to settle out of water.

b. After heavy rains, streams are turbid because of their high flow. Lakes and ponds are generally clearer than streams. Ground-water (well water) is clearer than surface water because the suspended solids have been filtered out by its slow movement through the soil.

c. Two methods are effective for removing turbidity from water: settling called sedimentation (pars. 32 and 33); and filtration (pars. 37 and 38).

d. Turbidity must be removed because the suspended particles may contain imprisoned germs, because soldiers prefer to drink clear but contaminated water instead of turbid safe water, and because the continued drinking of suspended solids may irritate the intestines and cause diarrhea.

19. Color

Most color in water is caused by dyes from decaying vegetation. True color must be distinguished from the apparent color caused by turbidity because the methods of removal differ. Water from swamps, weedy lakes, and streams is most likely to be colored. To

remove color, consult paragraphs 33*d* and 42*b* (2). Colored water is objectionable principally because it looks unpleasant.

20. Tastes and Odors

Tastes and odors occurring together in water are caused by algae (minute water plants), certain gases, and some industrial wastes. Taste alone may be caused by certain minerals in solution. Almost all surface water has odor, which may be anything from faint to highly disagreeable. Ground water generally has less odor than surface water, and cold water has less taste and odor than warm water. Many disagreeable tastes in water are increased by chlorination. The addition of fish oil or bone oil to water gives it such a disagreeable taste and odor that the water is unsatisfactory for drinking. Taste and odor removal are discussed in paragraphs 42 and 43.

21. pH Value

a. The minerals and other chemicals which water picks up (dissolves) as it flows over and through the soil greatly affect some of the purification processes such as coagulation and sedimentation. (See ch. 3.) Many of these dissolved minerals are acidic (vinegary) while others are alkaline (like lye). As water may contain both acidic and alkaline minerals, it is very helpful to know whether there are more acidic substances in it than alkaline ones. The pH value is the measure of the strength of the acidity or alkalinity of the water. It is useful for determining the amount of chemicals to add to the water for good coagulation (par. 58), for controlling the operation of the portable and mobile purification units, and for detecting poisons in water. (See par. 61.)

b. The pH value is determined in the Army by a color comparator (par. 57) and is measured on a scale (fig. 4) with 14 divisions. This scale covers both acid and alkaline conditions, with a pH of 0 representing maximum acidity, and a pH of 14 representing maximum alkalinity. At the midpoint of this scale, pH 7, the water is



Figure 4.

neutral; in other words, the acidic and alkaline substances in the water balance or cancel each other. The pH value of a water can be increased by adding alkaline substances like soda ash or decreased by adding acidic substances like alum. However, because disease-producing organisms do not change the pH enough to notice, pH is not a test of the purity of water.

c. As evidence that a pH of 7 does not mean purity, the pH values of many common foods are listed in table 3. Note that most foods are acidic. The pH value used to produce the best treatment in the water purification processes ranges from 4.5 to 8.0. Thus, the pH values of drinking water are generally higher than the pH values of common foods.

Table III. Tabulation of pH value of certain common foods

| | | | |
|-------------------------|---------|----------------------|---------|
| Apples | 2.9-3.3 | Olives | 6.3-6.6 |
| Bananas | 4.5-4.7 | Oranges | 3.0-4.0 |
| Beans | 5.0-6.0 | Peaches | 3.4-3.6 |
| Beers | 4.0-5.0 | Pears | 3.6-4.0 |
| Bread, white | 5.0-6.0 | Peas | 5.8-6.4 |
| Butter | 6.1-6.4 | Pickles, dill | 3.2-3.6 |
| Cabbage | 5.2-5.4 | Pickles, sour | 3.0-3.4 |
| Cheese | 4.8-6.4 | Potatoes | 5.6-6.0 |
| Cider | 2.9-3.3 | Soft drinks | 2.0-4.0 |
| Corn | 6.0-6.5 | Spinach | 5.1-5.7 |
| Crackers | 6.5-8.5 | Squash | 5.0-5.4 |
| Eggs, fresh white | 7.6-8.0 | Sweet potatoes | 5.3-5.6 |
| Grapefruit | 3.0-3.3 | Tomatoes | 4.0-4.4 |
| Lemons | 2.2-2.4 | Turnips | 5.2-5.6 |
| Limes | 1.8-2.0 | Vinegar | 2.4-3.4 |
| Milk, cows | 6.3-6.6 | Wines | 2.8-3.8 |

22. Dissolved Minerals

The amount of dissolved minerals in water depends on the length of time the water is in contact with the minerals. Thus, deep-well water usually has more minerals in solution than shallow-well water. The following minerals commonly found in water are discussed briefly:

a. *Calcium carbonate*, from chalk, calcite, or limestone is alkaline and hardness-producing. It is only slightly soluble in water.

b. *Calcium bicarbonate* is formed when water containing carbon dioxide comes in contact with calcite or limestone. The carbon dioxide is only loosely bound to the calcium carbonate, and can be driven off by heat or chemicals. When water containing calcium bicarbonate is heated, it loses carbon dioxide and the remaining calcium carbonate becomes insoluble and settles out. This calcium carbonate forms scale in boilers and distillation units. In addition to

causing scale, calcium bicarbonate causes hardness and alkalinity.

c. Calcium sulfate or gypsum causes hardness in water. As it is more soluble in cold water than in hot, it separates from the water in boilers and forms scale on the boiler tubes.

d. Calcium chloride causes hardness in water. In steam boilers and distillation units, the heat changes it into an acid which rapidly pits the tubes.

e. Magnesium carbonate (magnesite or dolomite) and *magnesium bicarbonate* act the same in water as calcium carbonate and bicarbonate.

f. Magnesium sulfate or epsom salts adds to the hardness of water and forms scale in boilers. In amounts greater than 500 parts per million (ppm), it acts as a laxative.

g. Magnesium chloride has the same properties and effects as calcium chloride.

h. Sodium carbonate (soda ash) and *sodium bicarbonate* (baking soda) cause water to be alkaline. In steam boilers, hot-water heaters, and distillation units, these chemicals break down and release carbon dioxide which corrodes the metal tubes.

i. Sodium chloride (table salt) causes a noticeable taste if present in amounts greater than 400 ppm. In amounts greater than 3,000 ppm, sodium chloride makes water almost undrinkable.

Note. Normal sea water has approximately 34,000 ppm of salt.

j. Sodium sulfate (glauber salts) has a laxative effective in amounts over 500 ppm. In large amounts, it causes foaming in boilers and distillation units.

23. Iron and Manganese

a. A common and troublesome impurity found in deep-well water is dissolved iron in the form of ferrous bicarbonate. As soon as water containing this impurity is exposed to air, oxygen changes the iron into insoluble oxides which give the water a rust color and cause stains. The fine red particles settle out as a rusty sediment. If the oxidized iron is not removed, the water has an unpleasant appearance and taste. For methods of removal of this impurity, see paragraph 44.

b. Water handled in steel pipes can pick up iron if the water contains dissolved oxygen or carbon dioxide. This trouble, is likely to occur in little-used pipes, dead-end mains, or when water of very low pH is supplied.

c. Iron in water may be accompanied by heavy growths of a bacteria called "Crenothrix" which oxidizes the iron, causing the rust colored or "red" water, pipe clogging, and bad tastes and odors. Trouble may be expected if there are more than 0.3 ppm or iron in the water. (See ch. 3 for treatment methods.)

d. Manganese in water is not encountered as often as iron, but it is found in both surface and ground water. Although its properties and methods of removal are the same as those for iron, its effects are more severe.

24. Dissolved Gases

a. HYDROGEN SULFIDE. Occasionally, water contains hydrogen sulfide, a dissolved gas which gives the water a disagreeable rotten-egg odor. In small amounts this impurity is unpleasant but not dangerous. In large amounts it is harmful. Water which contains organic matter will pick up hydrogen sulfide if it comes in contact with minerals containing sulfates.

b. OXYGEN. Rain water contains large amounts of dissolved free oxygen, while ground water seldom has as much. The amount of dissolved oxygen in surface water depends on the amount of pollution, which depletes the oxygen content, and on the action of algae. (See par. 31.) Oxygen makes water corrosive to many metals, especially when carbon dioxide is also present.

c. CARBON DIOXIDE. Dissolved carbon dioxide comes from the air, decomposing vegetation, and from underground sources. In the water it forms carbonic acid which in turn helps to change insoluble calcium carbonate and magnesium carbonate to soluble bicarbonates. (See par. 22.)

25. Alkalinity

Most water contains some alkaline substances such as carbonates, bicarbonates, and hydroxides of calcium, sodium, and magnesium. Alkalinity is important to water purification equipment operators because it determines the kind and amount of chemicals used in the coagulation process. (See pars. 33 and 58.)

Section IV. POISONED WATER

26. General

Water may be poisoned by mistake or on purpose. Lead in water and certain industrial wastes are the two major types of accidental poisoning. Chemicals like these used in chemical warfare are the most important of the substances used to poison water deliberately. This section discusses the various poisons. See chapter 3 on how to detect and remove them.

27. Lead Poisoning

Because the human body cannot rid itself of lead, the continual

drinking of water containing small amounts of lead eventually causes lead poisoning. Soft or acid water such as rain or swamp water is likely to pick up lead, especially if it is run through lead pipes.

28. Fluorides

Fluoride in water is not a poison. Its only effect is to stain the teeth of some children. In adults, it is believed that fluoride may be beneficial to the teeth.

29. Chemical Poisons

Poisonous chemicals which may be used to poison water are:

a. **CHEMICAL WARFARE AGENTS.** Chemical agents are the greatest threat of large-scale poisoning, because they can be sprayed from airplanes or spread by aerial bombs and by shells over wide areas. See paragraph 61 for methods of detecting them in water.

b. **ALKALOIDS.** Alkaloids such as nicotine, strychnine, or colchicine can be used to poison small water sources. Generally, they are too difficult to obtain for large-scale use.

c. **ORGANIC ARSENIC COMPOUNDS.** Organic arsenic compounds called arsenicals have the same limited use as alkaloids.

d. **INORGANIC ARSENIC COMPOUNDS.** Inorganic arsenic compounds called arsenites and arsenates are more common than the organic form. These compounds are the basis of many rat and insect poisons. For methods of detection see paragraph 61.

e. **CYANIDES.** Cyanides represent a definite threat while in enemy industrial areas. These compounds, common in plating and other metal industries, are highly soluble and poisonous in water.

f. **HEAVY-METAL SALTS.** Very few heavy-metal salts are soluble enough to poison water. The more soluble ones are the acetates and nitrates of lead and mercury.

CHAPTER 3

WATER TREATMENT PROCESSES

Section I. WATER PURIFICATION

30. General

a. Field water purification consists in removing or destroying enough impurities in water so the water is safe and pleasant to drink. The first and most important step in purification is to select the correct treatment processes and then to arrange them in the right order to do the job. This chapter discusses each treatment process in detail. Chapter 6 discusses the arrangement of processes.

b. Generally, good results are obtained by the following arrangement of water treatment processes: coagulation, sedimentation, filtration, and disinfection. However, specific purification problems often require additional treatment processes or a different arrangement. No one treatment process is a cure-all.

c. Methods of purifying water which has not been deliberately poisoned are covered in this section; treatment of poisoned water is discussed in the second section; and routine control tests are discussed in section III, this chapter.

31. Self-Purification

a. GENERAL. Under favorable conditions, a polluted body of surface water is often partially purified by natural agencies. This self purification cannot be depended on to effect complete purification (recovery), but it may decrease the load on mechanical purification equipment.

b. STREAMS OR RIVERS. (1) Slight pollution may be difficult to detect, but gross pollution is easily seen and the recovery of the stream is easily traced. Immediately below points of pollution, such as sewer outlets, turbidity is high and within a short distance the water turns black. Odorous sulfur compounds are formed and solids settle on the bottom, forming a sludge. The settled solids and sludge soon decompose, forming gases such as ammonia, carbon dioxide, and methane or marsh gas. These gases may form so rap-

idly that the surface continually bubbles. In still waters scum may form. Life in the water is confined to anaerobic bacteria, larvae of certain insects such as mosquitoes, and a few worms. There are no fish; turtles are generally the only form of higher life. The stream becomes clearer as it continues, allowing sunlight to penetrate the water. Oxygen dissolves from the air at the water's surface, permitting bacteria to start changing organic matter into nitrates, sulfates, and carbonates. These, together with the carbon dioxide produced from decomposition caused by the anaerobic bacteria, are plant foods. With sunlight now penetrating the water and with abundant food, algae flourish and form a green scum over the surface. As soon as algae appear, self-purification proceeds rapidly, as they take in carbon dioxide, use the carbon, and give out oxygen to the water, thus oxidizing the remaining organic matter.

(2) As green algae appear, fish requiring little oxygen, such as catfish and carp, are also found; as the dissolved oxygen increases, more types of fish appear. After recovery, fish find the stream highly favorable, as the algae support various aquatic insects and other organisms on which fish feed. The water is clear or turbid according to the concentration of algae and may have odor for the same reason.

(3) Throughout the stages of recovery or self-purification, disease organisms are greatly reduced in number because of lack of proper food, unfavorable temperatures, and pH values of the water. *However, the water is still dangerous since all disease organisms have not perished.*

c. LAKES, RESERVOIRS, AND PONDS. Self-purification in lakes, reservoirs, and ponds is brought about by the same agents as in streams or rivers. However, currents are not as strong and sedimentation is more important. Sedimentation is often so heavy that large deposits of sludge, dead algae, and other vegetation build up on the bottom. In deep lakes and reservoirs, self-purification is aided by seasonal "overturns." This is simply an exchange of bottom water for surface water caused by the change in density of the water which occurs in the spring and fall.

32. Sedimentation

a. GENERAL. (1) Plain sedimentation is the natural settling of solids heavier than water without the addition of chemical coagulants.

(2) Solids heavier than water are held in suspension while water is moving, but settle to the bottom in still water. The time required to clarify water by sedimentation depends on the size of the sus-

pended particles. Large particles settle to the bottom in a few minutes, but very small particles, such as clay, may remain in suspension for several days. Plain sedimentation is seldom used alone to purify water, but is used as a preliminary process in preparing water for filtration.

b. TO REDUCE TURBIDITY. Plain sedimentation tanks or basins are often used to reduce turbidity in water drawn from swift streams, particularly after rainstorms. If the particles causing the turbidity settle rapidly, plain sedimentation may reduce frequent backwashing of filters.

33. Coagulation

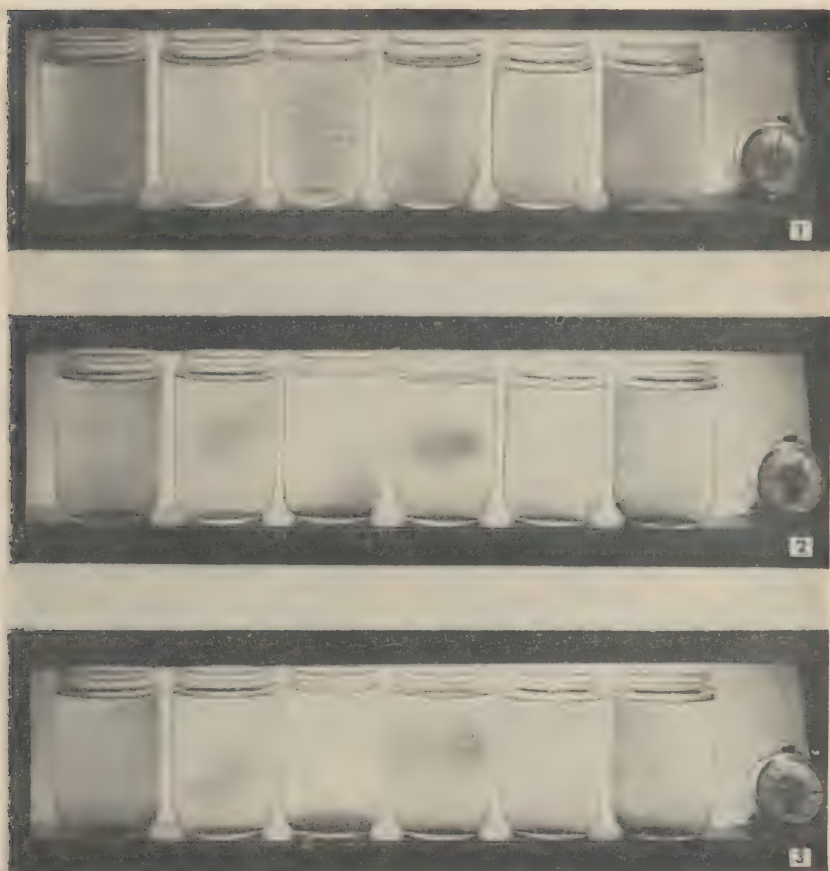
a. GENERAL. Coagulation is the process of adding a chemical to water to gather the suspended impurities into particles large enough to settle out rapidly. The standard chemicals for coagulation in the Army are filter or ammonium alums. They react with the alkaline substances in the water to form an insoluble jellylike substance which attracts the suspended silt and disease organisms to it. Chemically, these substances are aluminum hydroxide. If water does not contain enough alkalinity, it may be necessary to add an alkaline substance like soda ash to help form jellylike hydroxide.

b. FLOCCULATION. Ammonium alum, called the coagulant, can be added to the water in tanks, such as 3,000-gallon canvas tanks, or it may be added continuously to the water by mechanical feeding devices like those on the mobile and portable water purification units. With both methods, the water must be stirred after the chemicals have been added. The jellylike substance first appears as particles so small that the water has a milky appearance. In this form, the insoluble hydroxide will not clarify the water or settle out. It is necessary to continue stirring the water until the very small particles join with others to form large particles. This process is called flocculation and the large jellylike particles are called "floc." Operators should work to produce a heavy, rapid-settling floc. Note that flocculation is only one step in the process of coagulation, which also includes the adding of the chemicals.

c. OPTIMUM pH. Floc forms fastest and is heaviest at one definite pH value, called the "optimum pH." Because this optimum value changes with changes in the impurities in water, it is necessary to determine it by the jar test described in paragraph 58. Figure 5 shows a series of jars of different pH values. The third jar from the left is at the optimum pH because in this jar floc formed and settled out first. Optimum pH values generally fall between 4.5 to 7.5, depending on the impurities in the water. Colored water containing only a small amount of dissolved minerals generally

floculates best between pH values of 4.5 to 6.0, while turbid water with considerable natural alkalinity floculates best at pH values between 6.0 to 8.0. These values are only indications, as there is only one optimum pH for any given water. Optimum pH varies with rainfall, seasonal changes, etc.

d. COLOR REMOVAL. Generally color can be removed in floc when coagulating on the acid side of the pH scale. When alum is used, the water should usually be coagulated at a pH of 4.4 to 6.0. If the pH value is increased later, the color may reappear to a certain extent. Adding soda ash during coagulation may fix the color and prevent removal. Activated carbon (par. 42b (2)) can also be used to remove color.



1. Before settling has started.
2. After 5 minutes of settling.
3. After 15 minutes of settling.

Figure 5. Formation of floc in jar test. (Test shows that third jar from left is at optimum pH.)

e. MIXING COAGULANTS. To obtain satisfactory coagulation, coagulating chemicals must be thoroughly mixed with the water. In units using feed devices, this is done by adding the chemicals on the suction side of the pump so the pump impeller mixes them thoroughly. When coagulants are added by the basket method (fig. 6) in batch treatment, excellent mixing can be obtained by hanging the basket along the wall of a tank and filling the tank at high rates so it fills in about 15 minutes. Inlet hoses should be directed along one side of the tank, so a rapid swirling motion is set up throughout the tank. This distributes the chemicals throughout the water effectively.

f. ACCELERATING FLOCCULATION. To obtain best flocculation in the minimum time, the rate of floc formation should be accelerated by agitating the water. This is done best by "tapered" mixing, the water being agitated vigorously while the chemicals are being added and then more and more slowly over a period of about 30 minutes. When coagulants are added to water as it enters a sand filter, the flocculation period is brief and agitation is not continuously controlled. For waters that do not flocculate readily, this process does

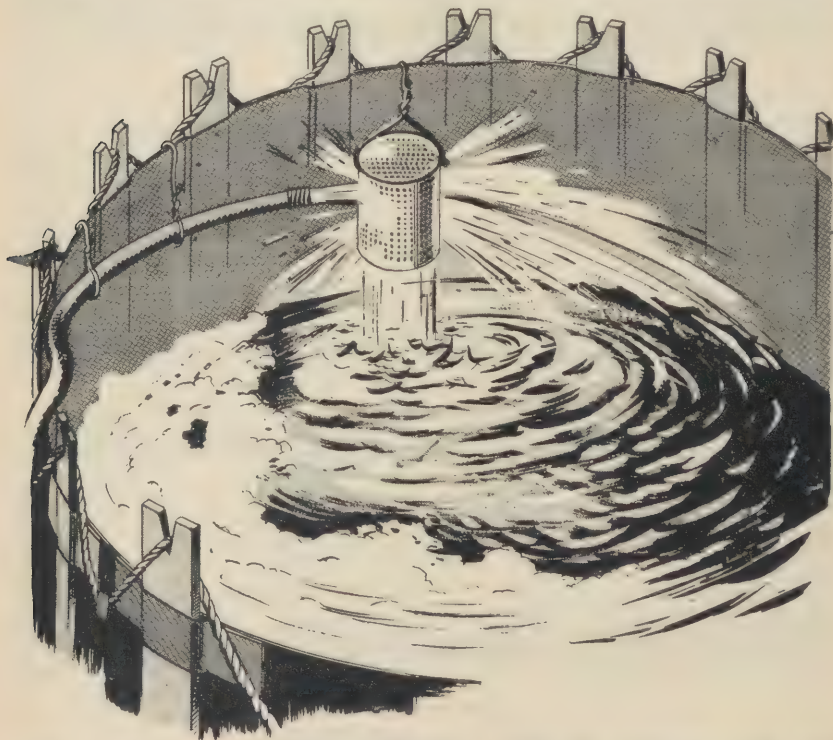


Figure 6. Wire basket (fig. 64) containing coagulating chemicals being used to pretreat raw water in 3,000-gallon canvas tank. The basket should not be placed closer to the hose than shown.

not assure reliable clarification by the filter and complete pre-treatment (par. 36) should be used.

34. Chemicals Used in Coagulation

The chemicals commonly used in coagulation are discussed below and in table IV. Alum coagulants are generally used with Army purification equipment.

a. ALUM COAGULANTS. (1) *Alum.* Filter alum or aluminum sulfate is available either in lump, granular, or powdered form. It is an acid salt and hence is corrosive to most metals. It is readily soluble in water and is easily applied in solution or dry.

(2) *Black alum.* Black alum is filter alum which contains 2 to 5 percent by weight of powdered activated carbon.

(3) *Ammonium alum.* Ammonium alum is used in mobile and portable purification units (pars. 63 through 71) and should not be confused with filter alum (aluminum sulfate). Use of ammonium alum facilitates controlled application of coagulant over a period of time because it is less soluble than filter alum, and, therefore, dissolves more slowly in alum pots and chemical baskets. It does not dissolve readily in cold waters. Alum pots are not accurate feeding devices, even with ammonium alum, but are more compact than other feeds.

(4) *Sodium aluminate.* Sodium aluminate is a coagulant used with alum for special treatment processes such as water softening and color removal.

b. FERRIC COAGULANTS. (1) *Copperas.* Ferrous sulfate, commonly known as copperas, is a granular acidic salt used with lime for coagulation. Lime must be added because the alkalinity and pH value of natural water are generally too low to react with copperas to form the desired ferric hydroxide floc.

(2) *Chlorinated copperas.* The oxidation of copperas by the dissolved oxygen of water occurs only at pH values above about 8.5. However, chlorine may be used to react with copperas irrespective of the pH value of the water. From this reaction, ferric sulfate and ferric chloride are formed and in turn act as coagulants.

(3) *Ferric sulfate.* Ferric sulfate is a dry commercial coagulant.

(4) *Ferric chloride.* Three commercial forms of ferric chloride are available: liquid, crystalline, and anhydrous material.

(5) *Summary of ferric coagulants.* Chlorinated copperas, ferric chloride, or ferric sulfate may be used in place of alum coagulants. There are a number of practical differences between alum and ferric coagulants, however, which should be noted. Briefly, these are as follows:

Table IV. Properties of chemicals used to coagulate or adjust alkalinity of water

| Chemical | How used | How shipped | Weight (pounds per cubic foot) | Dose (grains per gallon) | Effective pH range | Natural al- kalinity re- quired in grains per gal- lon to react with one grain per gallon of coagulant | Artificial alkalinity required to react with one grain per gallon of coagulant | | | Remarks |
|--|---|---|---|-----------------------------------|---|---|--|---------------|-------------|--|
| | | | | | | | Hydrated lime | Quick lime | Soda ash | |
| Alum..... $\text{Al}_2(\text{SO}_4)_3$ 18 H_2O | Coagulant | 200-lb bags..... 400-lb bbls..... Bulk | 39 | 0.3 to 3.0 | 4.4 to 6.0 5.7 to 8.0 9.0 to 10.5 | 0.45 | 0.35 | 0.28 | 0.48 | 4.4 to 6.0 pH range used for highly colored wa- ter. 5.7 to 8.0 pH range used for turbid and moder- ately colored water. 9.0 to 10.5 pH range used in alum coagula- tion of carbonates in lime-soda softening. |
| Ammonia alum..... $\text{Al}_2(\text{SO}_4)_3$ $(\text{NH}_4)_2\text{SO}_4$ 24 H_2O | Coagulant | 400-lb bbls..... 100-lb kegs | 39 ± | 0.3 to 6.0 | 5.7 to 8.0 | 0.29 ± | 0.23 ± | 0.18 ± | 0.31 ± | Less soluble than filter alum and costs three times as much in terms of aluminum- oxide content. There- fore use generally re- stricted to swimming pools and pressure fil- ters where "alum pot" is used. Ammonium content available. |
| Sulfuric acid..... H_2SO_4 | To adjust pH in connec- tion with alum coagu- lation. | 10-gallon carboys 500-lb steel drums 1, 500-lb steel drums | (Liquid) 18 lb per gallon | 0.1 to 1.0 | | | | | | Always dilute by adding acid to water, other- wise serious burns may result. Can be fed by use of hypo- chlorite-solution equipment. |

| | | | | | | | | | |
|--|-----------|--|---------------|------------|---|---------------------------------|---------------------------------|-------------------|---|
| Sodium aluminate $\text{Na}_2\text{Al}_2\text{O}_4$ | Coagulant | Solid—108-lb thin-steel drums 405-lb thin-steel drums 100-lb bags Liquid—32% $\text{Na}_2\text{Al}_2\text{O}_4$ steel drums 10' NaOH . | 58 \pm | 0.2 to 2.0 | 6.0 to 7.5 (with alum) 9.5 to 10.5 (softening) | | | | Used with alum to assist in the coagulation of cold water. Also used with alum to coagulate alkaline waters, such as with water softening. Supplies alkali as well as aluminum. Commercial grade contains 55% aluminum oxide and 35% combined soda plus 6% excess caustic soda. |
| Copperas (Ferrous Sulfate), FeSO_4 | Coagulant | 200-lb bags 400-lb bbls Bulk | 46 \pm | 0.3 to 3.0 | 8.5 to 11.0 | 0.27 | 0.22 | Not normally used | |
| Chlorinated copperas. | Coagulant | See copperas. | See copperas. | 0.5 to 3.0 | 3.5 to 9.5 | 0.65 (See ferric coagulants) | 0.52 (See ferric coagulants) | Not normally used | Chlorine added to copperas. One pound of chlorine required for each 7.8 pounds of copperas used. |
| Ferric sulfate (ferrisul), $\text{Fe}_2(\text{SO}_4)_3$ | Coagulant | 200-lb bags 400-lb wooden bbls | 70 | 0.5 to 3.0 | 3.5 to 9.5 | 0.78 | 0.46 | Not normally used | If dry-feed machine is used, must have solution pot feeding two parts of water to each part of ferric sulfate. Used with lime for iron and manganese removal. |

| | | | | | | | | | | |
|--------------------------------------|---|--|------|---|------------|------|------|------|-------------------------|--|
| Ferric chloride. FeCl_3 | Coagulant. | Liquid—12-gal- lon carboys, 42% 8,000-gallon rubber-lined tank cars Crystals—55- gallon hard- wood bbls each 60% containing 435 lb. Anhydrous—100-lb steel drums. | 63 ± | 0.5 to 3.0 For pH adjust- ment. For permanent hardness re- moval; dose varies with hardness. | 3.5 to 9.5 | 0.92 | 0.72 | 0.58 | Not normally used | Very corrosive. Rubber- lined equipment must be used. Used with lime for iron and manganese removal. |
| Soda ash Na_2CO_3 | To adjust pH or remove permanent hardness. | 200-lb bags 400-lb bbls Bulk | 63 ± | 0.1 to 2.0 For pH adjust- ment. For permanent hardness re- moval; dose varies with hardness. | | | | | | Readily soluble and noncorrosive to wrought-iron or lead piping. May be used to prevent corrosion when hardness of wa- ter exceeds about 40 ppm. |
| Hydrated lime. Ca(OH)_2 | To adjust pH or remove carbonate hardness. | 50-lb paper bags | 50 ± | 0.1 to 3.5 For pH adjust- ment. For carbonate hardness re- moval; dose varies with hardness. | | | | | | Only slightly soluble and thus is fed as a suspension. Cheaper and more effective than soda ash. Used to prevent corro- sion irrespective of hardness of water. |
| Quick lime CaO | To adjust pH or remove carbonate hardness. | Wooden bbls, metal drums, waterproof bags, bulk. | 65 ± | 0.1 to 3.0 For pH adjust- ment. For carbonate hardness re- moval; dose varies with hardness. | | | | | | Must be slaked before used. Somewhat cheaper and more ef- fective than hydrated lime, but difficulty of handling limits its use to large plants. |

(a) Ferric hydroxide is formed at low pH values, so coagulation with ferric coagulants at pH values as low as 4.5 is possible.

(b) Ferric hydroxide is insoluble over a wider range of pH values than aluminum hydroxide.

(c) Ferric hydroxide does not redissolve at high pH values.

c. SPECIAL COAGULATION AIDS. (1) *Artificial turbidity*. Under certain conditions, materials such as bentonite, Fuller's earth, or local clays may be added to the water to create an artificial turbidity which increases the rate of floc formation and settlement.

(2) *Sulfuric acid*. (a) *General*. Sulfuric acid is occasionally used with alum as an aid in coagulating colored water. As this acid causes severe burns when in contact with skin or clothes, special safety precautions must be observed when using it.

(b) *Safety precautions*.

1. Handle containers of sulfuric acid with great care.
2. Avoid spilling the acid on skin or clothing.
3. Wear rubber gloves.
4. Keep a supply of water nearby.
5. Keep an alkaline solution handy, such as diluted soda-ash solution.
6. If sulfuric acid spills on the skin, wash the areas immediately with plenty of water, apply the alkaline solution, and protect the burn from the air.
7. If the acid splashes into the eye, wash the eyes repeatedly with water and apply olive or similar oil to the affected eye.
8. Remove acid-splashed clothing immediately and wash the body. Ordinary clothing gives no protection against sulfuric-acid burns.

35. Chemicals Used to Adjust pH

The chemicals commonly used to adjust pH values as an aid in coagulation are discussed below and in table IV.

a. SODA ASH. Soda ash (sodium carbonate) is highly soluble in water. It is used when waters do not contain enough natural alkalinity to react with the coagulant. The soda ash supplied for field use comes in briquettes which dissolve more slowly than ammonium alum. Soda ash should be procured by specification to contain at least 98 percent sodium carbonate, because this quality is assumed in the calculation of chemical doses.

b. LIME. Quick lime (calcium oxide) or slaked lime (calcium hydroxide) may be used to provide artificial alkalinity. They are also used in water softening.

36. Pretreatment

a. GENERAL. Pretreatment is the partial clarification of water by coagulation and sedimentation before filtration. It reduces the amount of suspended solids in the water to a uniformly low level and makes certain the production of high quality water regardless of the turbidity of the source. Proper pretreatment prevents rapid clogging of filters. Army filter equipment operating on pretreated water should produce filtered water with turbidity lower than 0.3 ppm and rarely higher than 3 ppm.

b. EQUIPMENT. Water may be pretreated with standard settling tanks, pumps, pipe or hose, and chemicals. In the field, the 3,000-gallon or 500-gallon fabric tanks are used for coagulating and settling the water, and the issued pump and engine sets are used for filling and emptying the tanks. The principles outlined here can be used with the larger equipment normally available for permanent and semipermanent installations. Installations of coagulating and settling tanks are discussed in paragraphs 167, 168, and 169. Tanks are usually arranged for batch operation but may be used as continuous-flow units, when tankage is scarce and batch treatment will not produce enough water.

c. BATCH PRETREATMENT. When pretreating water by batches, one or more tanks are usually installed between the purification unit and the water source. The arrangement may be modified with the portable unit by installing the tanks between the pump and treatment assembly and the filter (fig. 155) to permit machine feeding of coagulants. A standard arrangement (fig. 169), consists of two or more tanks in parallel which allows the filter unit to operate continuously while pretreatment proceeds by batches. Coagulating chemicals are added manually to the water in the tanks or by a wire basket (fig. 64) hung in the inflowing stream. (See fig. 6.) With either method, the water in the tank should be rotated or swirled by the stream and the chemicals added during the filling period. Before the tank is full, pH should be checked and chemicals adjusted so optimum pH results when the tank is full. Floc containing the suspended matter settles out as the swirling subsides. The clear water can be removed either through a suction hose hung over the wall of the tank or through the side outlet. Often, use of the side outlet picks up less sludge than the hose over the tank wall. Clarification improves as some sludge accumulates in the tank.

d. CONTINUOUS-FLOW PRETREATMENT. (1) *Use.* When enough tanks are not available for efficient batch pretreatment, a single 3,000-gallon fabric tank can be used for continuous-flow pretreatment of the water for the portable sand filter by pumping water containing coagulants and disinfectant into the bottom of the tank

and removing the clarified water at the top. (See fig. 157.) The equipment arrangement must provide for:

(a) Continuous feeding of coagulants at the proper rate to maintain the pH of water at the optimum.

(b) Prevention of water flowing directly from the tank inlet to the outlet (short-circuiting).

Note. This method is not recommended for the mobile purification unit, as the rate of flow through the pretreatment tank (approximately 60 gpm) is too fast to give enough settling time for clarification.

(2) *Installation.* For installation and operating instructions, see paragraph 167f.

e. **SETTLING TIME.** The time allowed for settling depends on the need of removing amoebic cysts and turbidity, and by the demand for the water. When treating water containing amoebic cysts with sets designed around rapid sand filters (portable and mobile units), the time required for settling is at least 1 hour. When removal of cysts is not a factor, 20 minutes may be enough. It may be necessary in some situations to shorten the settling time at the expense of short filter runs.

37. Sand Filtration

a. **GENERAL.** Sand filtration is the process of removing suspended matter from water by passing it through beds of porous material. The beds are usually layers of fine sand overlying layers of coarser sand and gravel. In water purification, filtration is one of the basic processes used for removal of turbidity, bacteria, or other suspended material. Filtration difficulties are due to two factors: suspended particles so fine that they pass through the filter bed; and amounts of suspended matter so large that the filter clogs rapidly. To reduce these difficulties, coagulation is commonly used to group small particles so they will collect on the bed and be filtered out, or to aid the removal of suspended matter by settling it out before the water goes through the filter.

b. **SLOW SAND FILTERS.** (1) Slow sand filters use no coagulant, but may use sedimentation basins to remove suspended solids which will settle out by their own weight. For successful operation the water flowing to the filter must have a turbidity less than 100 ppm. In slow sand filtration, water passes slowly through beds of fine sand at rates normally not over 3 to 4 million gallons per acre per day (0.05 gallons per square foot per minute). The process improves as suspended material removed from the water gradually coats the sand grains. This type of filter should remove amoebic cysts and almost all the bacteria and suspended solids in the water. Properly operated filters absorb 30 to 40 percent of the coloring matter in water. When the sand bed becomes clogged reducing the

flow appreciably, the upper layer of sand and accumulated muck is scraped off. Time between cleanings may be as short as 2 weeks. These scrapings are washed and the clean sand is added to a reserve stock pile of filter sand. After the sand bed has been scraped 4 or 5 times (never to more than half its original depth), sand from the stock pile is added to restore the bed to its original depth (27 to 48 inches).

(2) Generally, slow sand filters have little military value because they require fixed installations with very large filter areas, clear or easily clarified sources, and experienced designers. Where water sources are contaminated with amoebic cysts and where it is difficult to obtain diatomite filters, slow sand filters have the following advantages for permanent or semipermanent stations: they can be built of local materials; they require a minimum of mechanical equipment; and they can be operated with native labor.

c. RAPID SAND FILTERS. In using rapid sand filters, water is usually pretreated, the suspended solids being coagulated so they will not pass through the coarse-sand filter beds. Rapid sand filters can be either *gravity* or *pressure* type. They are generally operated at rates of about 2 gallons per square foot per minute. Filter rates employed in the Army's mobile and portable water purification units (pressure-type rapid sand filters) are somewhat higher. See table V for the filtration rates of the mobile and portable units. Rapid sand filters operate effectively at rates at least 50 times as great as those of slow sand filters. This is possible because they use coagulation to help in producing clear water and they have a backwashing arrangement which quickly removes accumulated solids. Rapid sand filters function primarily as straining agencies for the flocculated material in water, and benefit from the accumulated gelatinous material collected in the sand. Sudden changes in rate of flow must be avoided to prevent dislodging this accumulated material. The Army sand filter units can be operated to remove amoebic cysts and to produce filtered water of generally high quality by special measures of control ((5) below), but are not as effective as diatomite units.

(1) *Operating and filtration rates.* (a) To obtain maximum capacity with minimum weight of equipment, mobile and portable water purification units have high filtration rates. At the rated output of 60 gallons per minute (gpm), mobile units filter 6.24 gallons per square foot per minute. At the maximum rated output of 10 gpm, portable units filter 6.35 gallons per square foot per minute. Both units use alum and soda ash to assist in producing clear water.

(b) To produce as clear water as possible with mobile and portable units, always use the lowest rate which still produces the re-

quired quantity in the time allotted. In the portable and mobile units, the time available for the reaction of the coagulant with the natural or artificial alkalinity is extremely short; therefore, pre-treatment is always desirable for these units.

Table V. Filtration rates of sand filters

| Filter rate in gallons per square foot per minute | Portable unit (17-inch-diameter filter) (gallons per minute)* | Mobile unit (42-inch-diameter filter) (gallons per minute)* |
|--|---|---|
| 0.25 | 0.5 | 2.5 |
| 0.5 | 1.0 | 5.0 |
| 1.0 | 1.5 | 9.5 |
| 1.5 | 2.5 | 14.5 |
| 2.0 | 3.0 | 19.0 |
| 3.0 | 5.0 | 29.0 |
| 4.0 | 6.5 | 38.5 |
| 4.4 | 7.0 | 43.0 |
| 5.2 | 8.0 | 50.0 |
| 5.7 | 9.0 | 55.0 |
| 6.0 | 9.5 | 57.5 |
| 6.2 | 9.5 | 60.0 |
| 6.4 | 10.0 | |
| | | 61.0 |
| 7.0 | 11.0 | 67.5 |
| 7.3 | 11.5 | 70.0 |
| 7.8 | 12.0 | 75.0 |
| 8.0 | 12.5 | 77.0 |
| 8.3 | 13.0 | 80.0 |
| 9.0 | 14.0 | 86.5 |
| 9.4 | 15.0 | 90.0 |
| 10.0 | 16.0 | 96.0 |
| 10.4 | 16.5 | 100.0 |
| 11.0 | 17.0 | 106.0 |
| 12.0 | 19.0 | 115.5 |
| 13.0 | 20.5 | 125.0 |

* Values are given to the nearest $\frac{1}{2}$ gallon per minute.

(2) *Washing filters.* (a) Floc and dirt must be removed from filters at frequent intervals. Pressure-type rapid sand filters are washed when putting the unit in service, when the loss of head through the filter is about 10 pounds per square inch (psi), when the filtered water becomes unsatisfactory, or when shutting down the unit. The operating period between the time a filter is placed in operation and the time it is washed is called a "filter run."

(b) Filters are washed by reversing the flow of water through them. The upward flow floats the sand and dirt, expanding it 30 or 40 percent of its normal volume. The grains of sand rub against each other, and the dirt and floc are scrubbed off and washed out of the filter. Washing should continue until the water coming out is as clear as that going in. The washing rate should be as high

as possible without washing the sand from the unit. When the filter is placed in operation after washing, filtered water is run to waste until loose suspended matter in the sand is flushed out and until chemical dosage is properly adjusted. The procedure for washing filters of various Army purification units is discussed in chapter 4.

(3) *Source of backwash water.* Army rapid sand filters are designed for backwashing with untreated and unfiltered water. When ample filtered or pretreated water is available, it should be used to prevent contaminating the filter bed. Care must be taken to avoid contaminating clear water with an unclean suction hose.

(4) *Operating difficulties.* (a) *Air-binding.* The filter may become air-bound by bubbles in the sand and discharge system. These bubbles appear when dissolved gases escape into the sand from the water. This escape may be caused by a reduction in water pressure, an increase in water temperature within the bed, or too much dissolved gas in the water. To prevent air-binding, avoid excessive negative (or suction) heads in the sand and keep the water from warming during the treatment process.

(b) *Mud balls.* Mud balls form in sand filters when sand grains are cemented together by gelatinous material strained from the water. They form on or near the surface of the sand and are relatively small. As the filter run continues, they increase in size and weight until they sink during backwashing. In time, they may make the filter ineffective. They are difficult to remove by backwashing. The most effective treatment is to replace the entire sand bed or to remove the balls by screening the sand. Improper leveling of the filter unit results in poor washing and may aid in mud-ball formation. Regular and thorough backwashing is an excellent preventive measure.

(c) *Channeling.* When mud balls or sticky coatings on the sand accumulate in a rapid sand filter, a condition called "channeling" may result, allowing unfiltered water to bypass the sand bed. The sand bed shrinks away from the filter sidewall or larger clogged masses in the sand may cause deep cracks to open up within the bed. When channeling occurs, screen and wash the sand to clean it. Inspect the filter bed at regular intervals, especially when clear water is not being produced.

(5) *Removal of amoebic cysts.* (a) When operating at high capacity rates, US Army sand filters of the mobile and portable purification units do not completely remove amoebic cysts. When cysts are present in the raw water, the portable unit should not be operated over 10 gpm and preferably not over 7.5 gpm, and the mobile purification unit should not be operated over 60 gpm and preferably not over 45 gpm. When operating either unit under these con-

ditions, water must be coagulated and allowed to settle in pretreatment tanks for at least 1 hour. Water treated under these conditions must be chlorinated to produce a residual of at least 1 ppm after a 30-minute contact period. If these conditions cannot be met, emergency chlorination (par. 41b(1)(b)) must be used.

(b) Remember that all surface waters in populated tropical and subtropical countries may be contaminated with amoebic cysts. In the United States, it is estimated that 5 to 10 percent of the population are carriers of amoebic dysentery.

38. Diatomite Filtration

Diatomite filtration is the process of removing suspended matter from water by passing it through a layer of diatomaceous silica. Diatomite filtration of pretreated water consistently produces a filtrate of less than 0.1-ppm turbidity, completely removes chlorine-resistant organisms such as amoebic cysts and cercariae of schistosomes, and removes over 90 percent of all bacteria. Approximately 1,000 gallons of water can be filtered per pound of filteraid. With careful operation, much greater yields can be obtained.

a. GENERAL. (1) *Description*. Special types of diatomite filters have been developed for use by the Army. These filters are included in sets of equipment containing pumps, tanks, and supplies that provide for pretreatment, chlorination, filtering, water storage, and water distribution. This equipment is described in paragraphs 74 through 85.

(2) *Filter characteristics*. To prevent rapid clogging of the original layer of diatomite filteraid by foreign matter in the water, the units are equipped with feeding devices which continuously supply fresh diatomite filteraid to the influent water. The rigid particles of filteraid mix with the compressible matter in the water to form a porous filter cake. When the resistance of this cake to flow becomes too great, it is removed by backwashing the unit and is replaced by a new filter layer. When filtering pretreated water, filtered-water quality does not depend on pressure or flow rates. Reduced pumping rates are not required to obtain clear water.

(3) *Diatomite and septums*. Diatomite, sometimes called diatomaceous earth, or filteraid, consists of the skeletal remains of minute algae, called diatoms, found in marine deposits which have been lifted above sea level. This crude diatomite is quarried and processed as diatomaceous-silica filteraid, which is inert to water and water-treatment chemicals. When used as a filter medium, diatomite requires a rigid supporting base or septum (fig. 53) porous enough to permit maximum flow without significant loss of head, yet fine enough to support the filter cake. For this purpose, cylindri-

cal elements of helically wound wire, porous rubber, or porous refractory minerals are most satisfactory.

b. PRECOATING. A precoat layer of filteraid is deposited on the cylinder by circulating diatomaceous slurry through the unit. At least 0.1 pound of filteraid is used per square foot. An almost uniform coating is formed over the entire septum since flow is greatest through the thinnest portion of the coating. *If flow is stopped during a filter run, the filter must be backwashed and a new precoat applied.*

c. FILTRATION. During the filter cycle, the porosity of the filter cake is maintained by the slurry feeder. Unless filteraid is added, compressible particles in the raw water will form a slime over the surface of the precoat layer, causing filter runs as short as 5 or 10 minutes. By adding filteraid slurry during filtration, the cake surface continually increases and the porosity is maintained longer. The quantity of slurry feed required depends on the character and amount of suspended solids in the unfiltered water. With relatively clear raw water or with well-coagulated and settled water, filter cycles last several hours without continuous slurry feed. The optimum filteraid slurry feed is determined by trial, using varying quantities of filteraid during a series of filter cycles and comparing the results.

d. BACKWASHING. Diatomite filters are backwashed by reversing the direction of flow and drawing *filtered* water from the storage tank through the filter. It requires less than 3 percent of the filter output to dislodge and remove the clogged filter cake. Diatomite filters should be backwashed whenever the porosity of the filter cake has decreased to a point at which filter output falls off noticeably.

e. ADVANTAGES OF DIATOMITE FILTRATION. The principal advantages of diatomite filtration are its superior quality of filtered water, and uniformity of output.

39. Filter Press Units

The filter-press process involves straining of water through various types of filter media such as pulp fiber, cotton pads, or fibrous material of many kinds. A unit of this type is described in paragraph 91.

40. Filter Expedients

In emergencies, expedients may have to be used to filter water. Examples are a wool blanket or similar material, improvised rapid or slow sand filters, or filters made from local granular material. Im-

provised filters cannot be expected to remove bacteria or amoebic cysts.

41. Disinfection

a. GENERAL. Water must be disinfected because no single water purification process or combination of processes will reliably remove all disease-producing organisms from water. Disinfection is the process of destroying disease-producing organisms. This may be done by adding chemicals, such as chlorine gas, chlorine solutions, lime, ozone, iodine, or potassium permanganate; by exposure to ultraviolet rays; or by boiling.

b. CHEMICAL DISINFECTANTS. (1) Chlorine. Chlorine in various forms is almost universally used to disinfect water. The process of disinfecting water by adding chlorine is called *chlorination*. Chlorine is a greenish yellow poisonous gas $2\frac{1}{2}$ times heavier than air. It is very pungent, has a disagreeable odor, and is highly irritating to the membranes of the nose, throat, and lungs. Chlorine can be obtained in liquid form or combined with several other elements in powdered form. As liquid, chlorine is amber colored and $1\frac{1}{2}$ times heavier than water. It is stored under pressure in steel cylinders. When the pressure is released, the liquid turns to a gas, which is added to the water by a chlorinator in Army equipment. The most commonly used powder or granular form, calcium hypochlorite, contains loosely bound chlorine. When dissolved in water, the chlorine is readily given up, leaving calcium oxide. Solutions of calcium hypochlorite are added to water by a hypochlorinator. Hypochlorites contain approximately 70 percent available chlorine, and are known by such trade names as HTH, Superchlor, and Perchloron. Every effort should be made to limit storage of calcium hypochlorite to approximately 1 year, since it deteriorates with age with a gradual loss in chlorine content. Moreover, under unfavorable storage conditions, especially in warm, humid climates, the container corrodes rapidly with resultant loss of chlorine content. Both using units and supply agencies should store and replenish stocks on a basis which assures use of older stock first. Hypochlorite containers should be handled with care and be stored in a relatively cool and dry place. Partially corroded or damaged containers must be immediately separated from the others.

(a) Chlorine content. The amount of chlorine required to disinfect water depends on the organic content and pH value of the water, temperature the time of contact, and the chlorine residual required. The Army requires that a residual-chlorine content of 0.4 ppm be maintained at all times in the active parts of distribution systems *at fixed installations*; contact period must be at least

30 minutes. This contact period is not compulsory when water is taken from unpolluted wells. Wherever subsequent rehandling presents a definite hazard, a chlorine residual of 1.0 ppm must be maintained. *Field conditions* require a chlorine residual of 1.0 ppm after chlorine has been in contact with the water for 10 minutes; water must be held an additional 20 minutes before distribution. Within limits, as the chlorine concentration increases, the contact time necessary to produce killing action decreases. However, too high concentrations are not desirable because the taste and odor of chlorine are imparted to the water.

1. *Chlorine dosage* is the amount of chlorine added to a water.
2. *Residual chlorine* is the amount of chlorine left in the water after the demand of all chlorine-consuming agents has been satisfied.
3. *Chlorine demand* is the amount of chlorine which reacts with chlorine-consuming agents in a set time; it is the difference between chlorine dosage and residual chlorine. Chlorine demand varies with the nature and quantity of chlorine-consuming agents, the pH value and temperature of the water, and the contact period. Although some disease organisms will be destroyed by the time chlorine demand is satisfied, satisfactory destruction may not be effected until a moderately stable chlorine residual has been permitted to act for an additional length of time.

(b) *Disinfecting time*. In most water, chlorine demand is virtually satisfied 10 minutes after the chlorine dosage is added. If as much as 1-ppm chlorine residual remains after the 10-minute demand period, satisfactory action is usually effected after 20 minutes more of contact time. Therefore, the basic rule for *field chlorination* is to add enough chlorine to produce a chlorine residual of at least 1 ppm after a contact time of 10 minutes, and to allow an additional contact time of 20 minutes before the water is consumed. These are the minimum requirements for chlorinating water.

1. Amoebic cysts are difficult to destroy by ordinary chlorination methods. When cysts are suspected and the procedure given in paragraph 37c(5) cannot be followed, moderately clear water with a pH of 7 or less can be disinfected by adding enough chlorine to produce a residual slightly in excess of 2 ppm after a 30-minute contact period.
2. Where schistosomiasis is a problem and diatomite filters are not available, reasonable protection can be ob-

tained by adding enough chlorine to produce a residual-chlorine content of 1.0 ppm after 30 minutes contact.

(c) *Safety precautions.* Although chlorine gas is dangerous to breathe, it gives warning of its presence even in concentrations that are not injurious. Short, shallow breathing should be used in any chlorine concentration. Exposure to low concentrations in inclosed spaces causes nausea and coughing and exposure to high concentrations can cause death. Men do not realize that it is impossible for them to become hardened by continued exposure. Chlorine produces no cumulative effects, and recovery from mild exposure is usually complete. Chlorine is particularly irritating to persons afflicted with asthma and certain types of chronic bronchitis. For protection in emergencies, service gas masks should be readily available near but outside areas likely to be affected in case of accident. When chlorine is noticeable in the atmosphere, either by sight or smell, the following immediate precautions should be taken:

1. Close tank valve promptly.
2. Avoid panic. Chlorine is quickly detected by its pungent odor and greenish yellow color.
3. Refrain from coughing.
4. Keep mouth closed.
5. Avoid deep breathing.
6. Keep head high as chlorine seeks the lowest possible level.
7. Withdraw from affected area. The odor of the gas is so disagreeable even in minute quantities that all persons in the affected area will be aware of its presence.
8. If a leak develops in a cylinder valve, be sure the leaking cylinder is upright. This prevents the escape of liquid chlorine. Under these conditions, natural chilling by vaporization takes place and the escape of chlorine gas is slow.
9. Remove persons affected by chlorine to the open air away from all chlorine gas. Place patient flat on his back, keep him warm, and elevate his head slightly. Call medical personnel immediately.

Caution: When chlorine is shut off, do not allow unchlorinated water to flow to the distribution tank.

(d) *Break-point chlorination.* In certain waters, the chlorine residual does not increase steadily as the chlorine dosage is increased. Instead, it decreases abruptly after reaching a certain point and then increases once more as the dosage is strengthened further. The point at which the chlorine residual again begins to rise is called the "break-point." In many cases, break-point chlorination can be used to achieve better disinfection or taste and odor

removal. This is possible because the residual chlorine present after the break-point has been reached is active free chlorine, which is more powerful than the residual chlorine resulting from small doses of chlorine. In Army water purification, small doses of chlorine combine with the ammonia from the ammonium alum to form chloramines in the water. Use of ammonium alum in treating water generally makes it necessary to use high doses of chlorine to reach the break-point.

(e) *Chloramine treatment.* Disagreeable tastes and odors caused by chlorine can be prevented or reduced by adding ammonia to the water before adding the chlorine. The ammonia and chlorine combine to form substances called "chloramines," which prevent many of these tastes and odors yet still act as a disinfectant. Army purification units use ammonium alum with chlorine to form chloramines. The characteristics of chloramines are summarized as follows:

1. They prevent the formation of both chlorine and chlorine-compound tastes, but do not overcome tastes already present.
2. They permit using a larger chlorine residual without producing objectionable tastes; moreover, this residual lasts considerably longer.
3. A contact time not less than 30 minutes is required, since the germ-killing action of chloramines is not as rapid as chlorine alone.

(2) *Potassium permanganate.* Potassium permanganate is sometimes used to disinfect water, since it oxidizes organic matter and kills bacteria.

(3) *Lime.* Commercial water plants sometimes add lime to soften water. With this process, only skilled operation can produce satisfactory results.

(4) *Silver.* In the electrokadyne disinfecting process, silver is introduced into water electrically. The addition of silver in the form of a silver coin does not provide any disinfecting action and may introduce bacteria.

(5) *Individual disinfection.* For emergency field disinfection of water in small quantities, Halazone tablets are used. Halazone tablets are chloramine compounds used for field disinfection of water in canteens. (See par. 105.)

c. OTHER METHODS OF DISINFECTION. (1) *Ultraviolet ray.* In disinfecting water by ultraviolet rays, the water flows in a thin stream past or around special lamps which give off the rays.

(2) *Ozone.* Ozone (O_3) is made by an electrical discharge in dry atmosphere or in pure oxygen. It is only slightly soluble in water, and therefore requires thorough mixing with water to be effective.

This method is expensive and difficult and is not suited to all types of water purification.

d. MISCELLANEOUS EMERGENCY METHODS OF DISINFECTING WATER. (1) *Iodine*. Iodine may be used as a disinfectant instead of chlorine. Ten cubic centimeters (approximately 1 canteen capful) of tincture of iodine disinfects 36 gallons of water (one Lyster bag). The water should not be used for 30 minutes after the iodine is added. *Iodine should be used only in emergencies*, since the raw water may contain substances which would cause iodo-amine compounds of low disinfecting ability.

(2) *Chlorine solutions*. Chlorinated soda (Labarraque's solution) or chlorinated potash (Javelle water) may be used in emergencies as water disinfectants. Other solutions containing chlorine such as Chlorax (NaOCl) can also be employed.

(3) *Boiling*. In emergencies, water may be disinfected by boiling vigorously for at least 1 minute.

42. Taste and Odor Control

a. GENERAL. (1) Water having an unpleasant taste usually has an unpleasant odor, since both are derived from the same source. Taste and odor in water are most commonly caused by the death and decay of plant growths of the algae type. They occur most in the summer and least in the winter. Tastes and odors must be removed when they make water unpalatable.

(2) Army treatment methods make it possible to produce water that will be palatable. Some taste or odor of chlorine may at times be unavoidable, but this can be minimized by combining treatment processes. Use of ammonium alum to produce chloramines and of activated carbon to adsorb organic material are particularly helpful. Such treatment does much to prevent odorous combinations of chlorine with organic impurities in water. The odor of the water should never be noticeable.

b. METHODS OF REMOVAL. Taste and odor can be removed by several methods depending on the substance to be removed and the equipment available. The following methods may be used:

(1) *Aeration*. (a) Aeration is the process of exposing water to air, thus allowing volatile odor-producing materials to escape. Aeration is accomplished by spraying water into the air, passing air under pressure into the water, or allowing water to flow over cascades or through beds of coke. The process adds oxygen to the water, reduces tastes and odors caused by decomposition of vegetation, and liberates dissolved gases such as hydrogen sulfide.

(b) With Army purification equipment, the spray method of aeration is best. The water is recirculated in storage reservoirs or tanks by a booster pump and sprayed back into the tank by an ele-

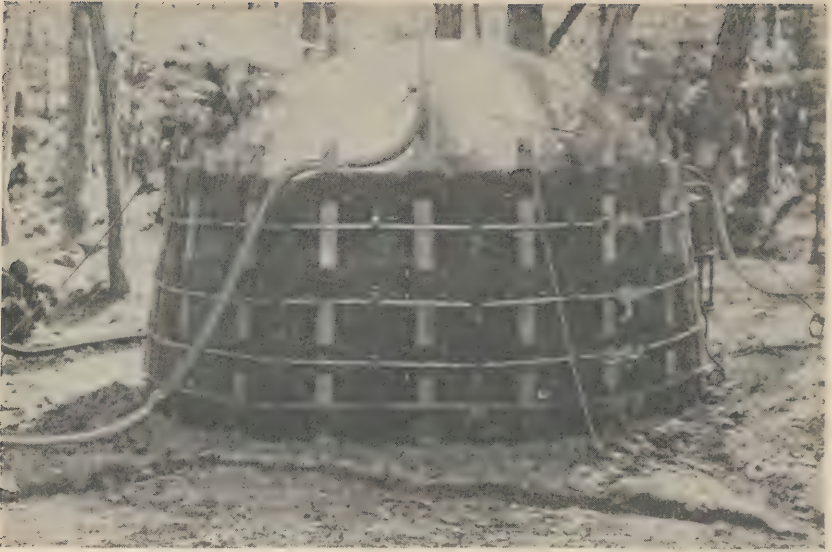


Figure 7. Aeration of water.

vated strainer attached to the end of the discharge hose. (See fig. 7.)

(2) *Activated carbon.* (a) Activated carbon is a relatively pure, finely powdered form of carbon which absorbs substances causing unpleasant taste and odor in water. It is an excellent absorption agent because the fineness and porosity of the carbon particles give an enormous surface area. One cubic inch of activated carbon has an internal and external surface exposure area of about 20,000 square yards.

(b) Activated carbon absorbs organic matter, chlorine, hydrogen sulfide, iron, chemical warfare agents, and is also valuable in removing color. The pH value or chemical characteristics of water are not affected by the addition of activated carbon, because it is totally insoluble in water. It may be added before, during, or after coagulation, or directly on the filters. Because it is insoluble, it tends to float unless all particles are thoroughly wetted before addition. Dosages of activated carbon as high as 1 pound per thousand gallons, may be required, depending on the impurities present in the water. One ounce per thousand gallons is usually enough. Much higher dosages are required for removing chemical warfare agents.

(3) *Copper sulfate.* (a) If tastes and odors are caused by small organisms in the water source, they may be controlled or prevented with copper sulfate. Copper sulfate is most frequently used in lakes and reservoirs and is applied either by towing a porous sack

of copper sulfate crystals behind a boat or by spraying a solution over the surface of the water.

(b) The amount used depends on the concentration and type of organism present. Caution should be exercised in the quantity used, although the amount necessary to remove microorganisms have no detrimental effect on human beings. Care should be taken to avoid killing fish in the water. Generally, a dose greater than 2.0 ppm of copper sulfate kills all fish in the water.

43. Removal of Bone or Fish Oil From Water

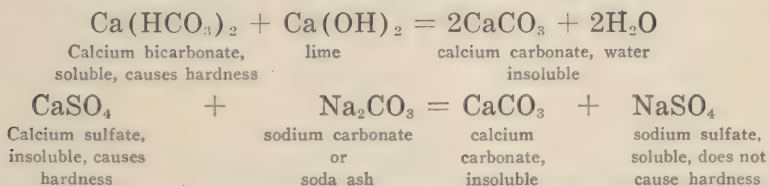
Wells contaminated with fish or bone oils are not used unless absolutely necessary. If the water *must* be used, the well is pumped to waste for 30 minutes to 1 hour or until its odor is less objectionable. The water is then pumped into storage tanks and allowed to stand for 1 hour. Because the specific gravity of these oils is less than water, water which is carefully withdrawn from the bottom of the tank without disturbing the surface film has a much less objectionable odor and taste. It is safe to drink if it has been treated properly to eliminate bacterial contamination and if tests show it is free of chemical warfare agents. Activated carbon may be used as an adsorbing agent for further removal of objectionable taste and odor, although unusually large doses may be required.

44. Iron and Manganese Removal

The characteristics of iron and manganese are so closely associated that steps for removing one are frequently effective in removing both. Iron and manganese in water can be oxidized to insoluble ferric oxide and manganic oxide by aeration. (See par. 42b(1).) After aeration, the iron and manganese floc should be settled out by sedimentation to keep it off the filters. It is more difficult to remove iron in conjunction with organic matter in water. In such cases, it may be necessary to add soda ash before aeration. The pH of the water should be increased to above 8.2.

45. Softening by Use of Lime and Soda Ash, and Zeolite

a. LIME-SODA METHOD. The chemistry of the lime-soda method of softening of water is indicated in the following typical chemical reactions: (See table XVIII for other reactions.)



(1) *Lime*. The first formula indicates the reaction which takes

place when lime reacts with *soluble* calcium or magnesium bicarbonates and forms *insoluble* calcium carbonate or magnesium hydroxide, which is precipitated.

(2) *Soda ash*. The second equation results when soda ash is added to raw water to react with the *soluble* calcium and magnesium sulfates or chlorides, forming *insoluble* calcium and magnesium carbonates which are precipitated. The soluble sodium sulfate and sodium chloride also formed remain in the water. Consequently, any hardness caused by calcium and magnesium sulfates or chlorides can be removed by use of the soda ash provided in Army water supply equipment sets. After the soda ash has been added, the water should be thoroughly mixed and allowed to settle before filtration.

b. **ZEOLITES**. Zeolites used in water softening are complex compounds of sodium, aluminum, and silica which have the faculty of exchanging bases. They are often called "green sand," because of the green color of natural zeolite. When water containing calcium and magnesium compounds passes over the zeolite, the calcium and magnesium are exchanged for the sodium in the zeolite. This chemical exchange softens the water and at the same time increases its sodium content. When the sodium of the zeolite is exhausted, it is regenerated by applying a solution of sodium chloride. An exchange is again effected and the brine is withdrawn as a calcium and magnesium chloride solution. The operating rate varies directly with the thickness of the zeolite bed. Zeolite water softeners may be operated at a rate up to 5 gallons per square foot per minute provided the zeolite bed is not exhausted in less than 3 hours. The time between regeneration depends on the character of the water and the rate of application. The need for regeneration can be noted when hardness is no longer removed. This process is not adapted to water with high turbidity or high iron content.

46. Corrosion Control

Water with a low pH corrodes steel tanks and piping. To prevent this, it may be necessary to adjust the pH of the filtered water by adding lime or soda ash. Corrosion control is not important in Army water supply, unless the water is to be transported by pipe line, carried or stored in metal containers for considerable periods of time, or used for special purposes. The pH of the filtered water can be raised by adding soda-ash solution to the filtered-water reservoir.

47. Water Treatment to Prevent Heat Fatigue

Troops undergoing strenuous or prolonged physical activity in

training or combat lose an excessive amount of salt through perspiration. This loss of salt can be prevented if all troops drink water containing approximately 0.1 percent of table salt. Drinking water containing the desired amount of salt can be prepared as follows:

1 pound of table salt to 100 gallons of water

0.3 pound of table salt to 36 gallons of water (Lyster bag)

48. Water Treatment to Remove Schistosomes

In areas in which schistosomiasis is prevalent, wells and springs not subject to contamination by drainage and surface run-off should be used in preference to natural bodies of surface water such as ponds and sluggish streams. Where these organisms are found, the safety measures discussed below must be taken by engineer water supply personnel using sand-filtration units.

a. PRETREATMENT. Pretreatment tanks must be used before the water is filtered. The coagulant dosage should produce a heavy, rapidly settling floc. This settling period must be at least 60 minutes.

b. FILTRATION. The filter rate must not exceed 6 gallons per square foot of sand area. Thus the maximum filter rate with the portable unit will be 10 gpm and with the mobile unit, 60 gpm. (See table V.)

c. DISINFECTION. For proper disinfection, the chlorine content after 30 minutes of contact with the water must be at least 1 ppm.

d. PROTECTION OF WATER SUPPLY PERSONNEL. Personnel operating water supply points should wear rubber gloves and rubber boots when they are required to wade or place their hands in untreated water.

e. STRAINING TO REMOVE HOST ORGANISM. Schistosomiasis can be partially controlled by straining the water before purification to remove the host of the schistosoma organism, a type of freshwater snail. Since the schistosoma organism cannot live outside the human body longer than 24 to 40 hours unless supported by a host organism, the strained water must stand at least that long before being purified.

Section II. TREATMENT OF POISONED WATER

49. General

a. Detection and treatment of poisoned water can be explained accurately only by using technical terms for the poisons and processes involved. This information is of primary interest to officers responsible for determining the amount of poison in the water

before treatment and the amount of poison remaining after treatment. Explanation of the mechanical operation of standard water supply equipment is for the operators who do the treating and for the supervisors who do the testing. (See par. 54.)

b. All personnel connected with water supply must be familiar with poisoned-water treatment methods. This is a necessary precaution, although there have been no reports of poisoned water sources during the present war other than those describing the use of bone oil and fish oil to make water unfit to drink.

c. There are four distinct steps in handling poisoned water:

(1) Detecting poison.

(2) Determining whether or not treatment is practicable.

(3) Treating.

(4) Testing treated water to verify effectiveness of treatment before delivering water for use.

d. *Every effort must be made to find an unpoisoned water source before considering treating water known to be poisoned.*

50. Personnel

Treatment of poisoned water must be closely supervised by the Medical Department or by qualified officers from engineer water supply units. For the responsibilities of various personnel, see paragraphs 53 and 54.

51. Poisons Which May Be Encountered

Many kinds of poisons may be encountered. Some may be placed in the water deliberately by the enemy or saboteurs; some may enter accidentally as a result of the tactical use of chemical warfare agents. The common poisons that may be encountered in water are given in paragraph 29.

52. Poisoning Effect of Chemical Warfare Agents

The poisoning effect of a chemical warfare agent in water depends on its strength, its degree of solubility in water, and its rate of chemical decomposition (hydrolysis) after it is in solution. Although highly poisonous in their natural form, some chemical warfare agents do not seriously contaminate water because they dissolve too slowly. Other agents, such as phosgene (CG) and di-phosgene (DP) in solution, decompose and form harmless products so rapidly that they do not poison water. The most dangerous agents are the blister gases and agents containing cyanide, because they are highly poisonous, are soluble in water, and either are slow to decompose in solution or remain poisonous after decomposition.

Table VI. Relative poisoning effect of chemical warfare agents in water

| Chemical agent | Symbol | Physiological effect in natural state | Poisonous effect in water | Remarks |
|---|-----------------|---|-----------------------------------|---|
| Nitrogen mustard | HN | Blister gas | Highly poisonous and dangerous. | Readily soluble in water. Requires several days to decompose in water (hydrolyze). Water containing nitrogen mustard is odorless and tasteless. |
| Lewisite Ethylchlorarsine | L ED} | Blister gases | { Highly poisonous and dangerous. | Quite soluble in water. Decomposes rapidly in water and remains poisonous. |
| Mustard | H | Blister gas | { Fairly poisonous and dangerous. | Fairly soluble, but is harmless several hours after decomposition. |
| Chlorpicrin Brombenzylcyanide Chloracetophenone | PS BBC CN | { Choking gas Tear gas Tear gas } | May be poisonous | Give water objectionable tastes and odors. |
| Adamisite Diphenylchlorarsine | DM DA} | Vomiting gases | May be poisonous | Slightly soluble in water. |
| Phosgene Diphosgene | CG DP} | Choking gases | Harmless | Soluble in water. Decomposes into harmless products. |
| Cyanogen Chloride | CC | Blood and nerve poisoning. | Highly poisonous and dangerous. | Decomposes slowly in water. |

Table VI compares chemical warfare agents in these respects. See FM 21-40 for a description of chemical agents.

53. Detecting and Testing Poisoned Water

a. GENERAL OBSERVATION. Observation sometimes discloses the presence of serious contamination although visual inspection alone is not reliable and must be confirmed by tests. Significant and suspicious indications of poisoned water must be reported immediately. Indications that should arouse suspicion are:

- (1) Unusual appearance, color, or odor in water.
- (2) Peculiar appearance of surrounding vegetation such as wilting or discoloration of leaves.
- (3) Dead fish or other dead aquatic life native to the water source.

(4) Reports of friendly natives, or the deliberate avoidance of the water source by the local population or by animals.

b. ROUTINE CONTROL TESTS. Some organic poisons can be detected by certain routine water-treatment control tests. For example, low pH readings and high chlorine demands are warnings of possible contamination. Discovery of such unusual values is reported, and the tests described in *d* and *e* below are made.

c. USE OF POISON-TESTING KITS. As a routine precaution whenever G-2 reports warn of the danger, *all* water sources are tested for poisons before use. Likewise, it may be necessary to test all new water sources in territory evacuated by the enemy. The tests are described in *d* and *e* below.

d. SCREENING KIT. (1) A simple water-testing and screening kit (kit, field, water-testing, screening, for chemical warfare agents) is issued to the medical officer of each battalion or similar unit and with each engineer water purification set. Directions for using the kit are contained in each kit and are given in paragraph 61. Simple tests made with this kit indicate pH readings and chlorine demand. Other tests with the kit indicate the presence in water of unsafe amounts of mustard (H), nitrogen mustards (HN), lewisite (L), ethyldichlorarsine (ED), and other chemical warfare agents or substances containing arsenic and cyanogen chloride. *This kit does not detect other cyanides or heavy-metal salts.* Large quantities of alkaloids and other organic poisons *may* be indicated by high chlorine demands.

(2) Tests with this kit are rough qualitative tests, indicating only the presence or absence of some poisons in water. If any single test gives a positive result, the water point is shut down and an attempt made to locate an uncontaminated source. The proper intelligence officer, Medical Department officer, and water-control officer

are notified at once. No attempt is made to treat the poisoned water until a qualified officer prescribes the treatment.

e. **TREATMENT-CONTROL KIT.** A more comprehensive and elaborate testing apparatus (kit, water-testing, poisons, treatment-control, for chemical warfare and other toxic agents) is issued to engineer water supply companies and to field hospitals for use by water-control or other qualified officers. Directions for its use accompany each kit. It is capable of quantitative measurements of mustard (H), nitrogen mustards (HN), lewisite (L), ethyldichlorarsine (ED), and other chemical warfare agents or substances containing arsenic in water. It also detects poisonous cyanides and heavy-metal salts, although the tests for these substances are qualitative only.

f. **SUMMARY.** See table VII for a summary of detection and treatment methods and their limitations.

54. Treating Poisoned Water With Activated Carbon

a. **GENERAL.** (1) Activated carbon is the principal material used in treating poisoned water. The carbon particles adsorb poisons (par. 42*b* (2)) and when the carbon is removed from the water, the adsorbed poison goes with it. The ordinary variety of unbranded carbon previously supplied to water supply units is not satisfactory for removing poisons. Better carbons bearing trade names such as Norit C-18, Nuchar C-115, or Nuchar AL are now being supplied and must be used for treating poisoned water. Requisitions should specify these products. The effectiveness of the carbon treatment varies with the kind of poison encountered, as shown in table VII.

(2) Distillation effectively removes mustard and lewisite, but the distilled water must be treated with activated carbon to remove tastes and odors.

b. **PRECAUTIONS TO BE OBSERVED.** (1) Treated water is not released for use until it has been tested and approved by the supervising Medical Department officer. Tests are described in paragraph 53*d*.

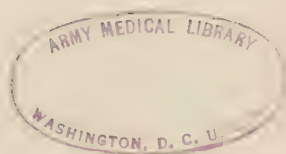
(2) To prevent possible cumulative effects, troops are not allowed to use water for more than 7 consecutive days if it has an arsenic residual as high as 20 ppm, expressed as ppm of lewisite.

(3) Operators handling water polluted with blister agents must be careful to avoid contact with undissolved droplets of the agents. Similar precautions are required to prevent contaminating pumps, tanks, or other treating apparatus with undissolved agents. Detection papers and materials and facilities for decontamination should always be readily available. (See FM 21-40.)

Table VII. Poisons in water: summary of detection and treatment methods and their limitations

| Poisons | Detection (a) Screening kit 1 (b) Treatment-control kit 2 (c) Routing control test 3 | Treatment |
|--|---|--|
| 1. Chemical warfare agents: a. Blister gases: Nitrogen mustards (HN) Lewisite (L) Ethylchlorarsine (ED) Mustard (H) | DB-3 test in (a) and (b) Arsenic test in (a) and (b) Chlorine demand in (a), (b), and (c) Arsenic test in (a) and (b) Chlorine demand in (a), (b), and (c) Chlorine demand in (a), (b), and (c) DB-3 in (a) and (b) with fresh contamination. | Remove by activated carbon. |
| b. Choking gases: Chlorpicrin (PS) Phosgene (CG) Diphosgene (DP) | Taste and odor Low pH in (a), (b), and (c) | Removed by activated carbon with difficulty. None necessary. (See par. 53.) |
| c. Tear gases: Chloracetophenone (CN) Brombenzylcyanide (BBC) | Taste and odor Taste and odor | Removed by activated carbon |
| d. Vomiting gases: Adamsite (DM) Diphenylchlorarsine (DA) | Arsenic test in (a) and (b) Arsenic test in (a) and (b) | |
| e. Blood and nerve poison: Cyanogen chloride | DB-3 test in (a) and (b) | Reduced by aeration, activated carbon, and chlorination. |
| 2. Physiologically active organic substances | Chlorine demand in (a), (b), and (c) | |
| 3. Organic arsenicals | Arsenic test in (a) and (b) | Generally removed by activated carbon. |

| 4. Inorganic arsenic compounds (arsenites and arsenates) | Arsenic test in (a) and (b) | Carbon ineffective in most cases. |
|--|-----------------------------|------------------------------------|
| 5. Cyanides | Cyanide test in (b) | Not removed by carbon |
| 6. Heavy-metal salts | Heavy-metal test in (b) | Not removed by carbon |
| 7. Bone oil and fish oil | Taste and odor | Removed by large amounts of carbon |

¹ See paragraph 53d.² See paragraph 53e.³ See paragraph 53b.

(4) Waste carbon sludge from this treatment should be buried.

c. CARBON TREATMENT. (1) *Amount used.* The standard and minimum amount of activated carbon used by the Army is 15 pounds per 1,000 gallons of poisoned water to be treated. This quantity satisfactorily removes up to about 30 ppm of most chemical warfare agents. If tests (par. 53c) show the contamination to exceed 30 ppm, the carbon dose is increased proportionately.

(2) *Sequence of operations.* With Army water purification units, poisoned water is treated with carbon before filtration or chlorination. Chlorine is never added to the raw water before filtration because it makes the removal of organic poisons with carbon more difficult and because the poisons consume so much chlorine that disinfection is unreliable. The carbon treatment consists of the following four steps:

(a) Adding enough carbon to reduce amount of poison in water to harmless proportions.

(b) Proper agitation of water and carbon during treating process.

(c) Setting of carbon from water.

(d) Testing treated water to be sure it is safe.

(3) Heavier doses of carbon are required to remove nonpoisonous contaminations of bone oil and fish oil, but the same method applies.

d. PROCEDURE FOR TREATING POISONED WATER. (1) *Testing poisoned water.* Sample and test the water source at several points or depths with the treatment-control kit and select a pump-intake point which yields raw water containing the least poison.

(2) *Installation for treatment of poisoned water.* Set up tanks as for batch pretreatment of water. If cyanogen chloride is present, provide for aeration of the water while filling the tank. When 3,000-gallon tanks are used, connect hose and valves to take settled water out through the side outlets.

(3) *Adding carbon.* Mix 5 pounds of carbon (c above) with water in a separate container and pour the mixture into the tank. The carbon may be added after the tank is full, but earlier application is desirable since it provides longer contact period.

(4) *Pumping water from source.* Fasten the pump suction hose far enough below the surface to avoid sucking in any floating particles or scum of undissolved agent, but far enough from the bottom to avoid sucking in undissolved settled droplets. Begin filling the tank with the poisoned water.

(5) *Agitating water and carbon.* Place a pump on each side of the tank and extend the intake hoses to the bottom near the center of the tank. While tank is filling, continually mix and agitate the water and carbon by circulating the mixture through the pumps.

To obtain good mixing, place pump discharge streams where they will create a swirling motion in the tank. Continue circulation through the two pumps for at least 15 minutes after the tank is full. When 500-gallon tanks are used, one pump is enough. *Thorough mixing during this phase of the treatment is extremely important to insure complete adsorption.*

(6) *Adding coagulants.* (a) In carbon treatment, ammonium alum and soda ash are used as coagulants. Use about 1 pound of ammonium alum per 1,000 gallons when the standard amount of carbon is used; for higher carbon dosages, increase coagulant dosages. Determine the amount of soda ash necessary to form a good floc by a coagulation test (par. 58), using a series of soda ash doses with the above alum dose. Ordinarily, approximately $\frac{1}{4}$ pound of soda ash per 1,000 gallons will be needed with this alum dose. If chemical solutions are to be used, determine the amounts of coagulating chemicals required far enough in advance so they can be dissolved and ready for use when required. Prepare the coagulating chemicals by placing the proper amounts in separate containers and dissolving them in water. Chemicals can also be applied by using the chemical baskets.

(b) At the end of the carbon treatment period, pour the chemical solutions in slowly or apply the chemicals in the chemical baskets.

(c) When the coagulants are well mixed into the water, stop circulation by pumping and allow the swirling motion to diminish naturally. This aids formation of a heavy floc and assists coagulation. Leave the tank undisturbed until visual inspection shows it to be clear enough for filtration.

(7) *Testing treated water.* Test samples of the settled water to determine the effectiveness of the carbon treatment. Tests are made with the treatment-control kit. (See par. 53e.) If it is not available, the screening kit (par. 53d) must be used. The treated water must be free of any taste or odor characteristic of the poison it contained. If the treatment-control kit is used, the water must meet the requirements of the appropriate test listed below:

(a) For nitrogen mustards (HN) or cyanogen chloride (CC), a negative or border-line test with the DB-3 reagent (absence of blue or yellow color) is required.

(b) For lewisite (L), ethyldichlorarsine (ED), or other arsenicals, test must show less than 20-ppm arsenic residual (expressed as ppm of lewisite).

(c) For mustard (H) and other organic poisons, the chlorine demand must be less than 5 ppm.

(8) *Procedure if tests are unfavorable.* If the tests show that the treated water is still unsafe because the residual-poison content

is above permissible levels, repeat the carbon treatment with fresh carbon. Add fresh carbon directly to the original treatment tank and mix it with the used carbon by stirring the water with the pumps. The used carbon aids re-treatment and promotes faster settling the second time. Re-coagulate and settle.

(9) *Testing re-treated water.* Test re-treated water again.

(10) *Cleaning tanks.* When it is necessary to disassemble a tank used for treating water containing blister gases, scrape the tank to loosen accumulated sludge, being careful not to puncture tank. Remove and bury sludge and flush tank with water.

e. FILTERING AND CHLORINATING WATER. (1) *Portable sand filter.* (a) After the water is declared safe, attach the intake hose of the pumping set to the valve at the bottom of the treatment tank. Set up a clean 3,000-gallon tank to receive the discharge, and proceed with filtration and chlorination as described in TM 5-2000 with the following changes and precautions:

(b) Omit coagulation (application of alum and soda ash).

(c) Control rate of filtration carefully to prevent fine carbon particles passing through the sand filter.

(d) Chlorinate either by the hypochlorinator in the treatment section of the unit or by batch chlorination in the 3,000-gallon receiving tank. With the hypochlorinator, an extra length of rubber hose is used to connect it to the filtered-water sampling connection on the filter. Test the water for chlorine residual before releasing it for use. The test must show 1 ppm after a 10-minute contact period. If the contaminating agent was mustard (H), an additional chlorine demand may result from the products caused by chemical decomposition of the mustard gas in the water. If chlorine residual falls below 1 ppm for this or any other reason rechlorinate the water.

(2) *Mobile water purification unit.* (a) *Limitations.* The full capacity of the mobile water purification unit cannot be used in the carbon-treatment method because poisoned water must be carbon-treated in batches, which prevents a continuous intake from the raw-water source.

(b) *Modifications.* Procedure with the mobile unit is the same as that with the portable sand filter except for the following modifications: At the start of the treatment process, the mobile unit's pump can be used for filling the pretreatment tank with poisoned water by using the bypass connection. If available, use a 55-gpm pump to circulate the water until the tank is full. After filling, use both pumps and continue circulation for at least 15 minutes. Where only the mobile unit's pump is available, circulate water for at least 30 minutes with the pump working at maximum capacity. Coagu-

late, test, filter, chlorinate, and store the water as in (1) above.

f. PROCEDURE USING DIATOMACEOUS-SILICA FILTERS. Pretreatment methods for diatomite filters are essentially the same as those for sand filters. However, it may not be necessary to use coagulants before filtration. To avoid overloading the filter, allow at least 20 minutes for most of the carbon to settle before starting filtration. Test, filter, and store the filtered water. Use batch chlorination for the filtered water. Do not prechlorinate.

Section III. ROUTINE CONTROL TESTS

55. Water-Quality-Control Set, No. 1, for Field Use

a. GENERAL. The field water-quality-control set is a compact portable chest of equipment and supplies for water reconnaissance and routine water control in the field. Water must be tested in the field to identify and measure impurities and determine the treat-

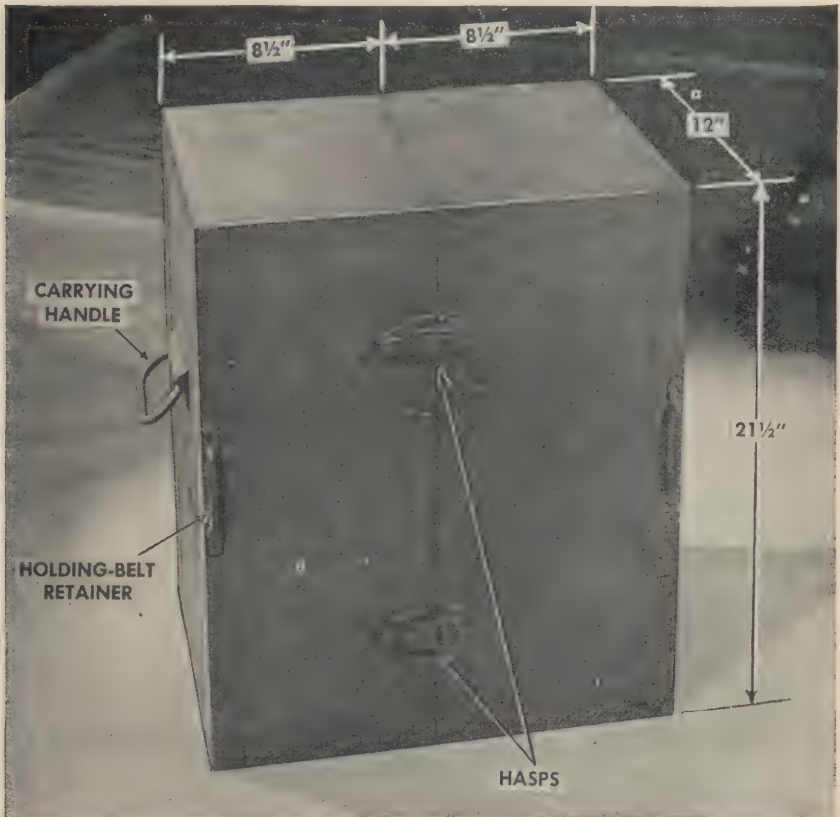


Figure 8. Field water-quality-control set.

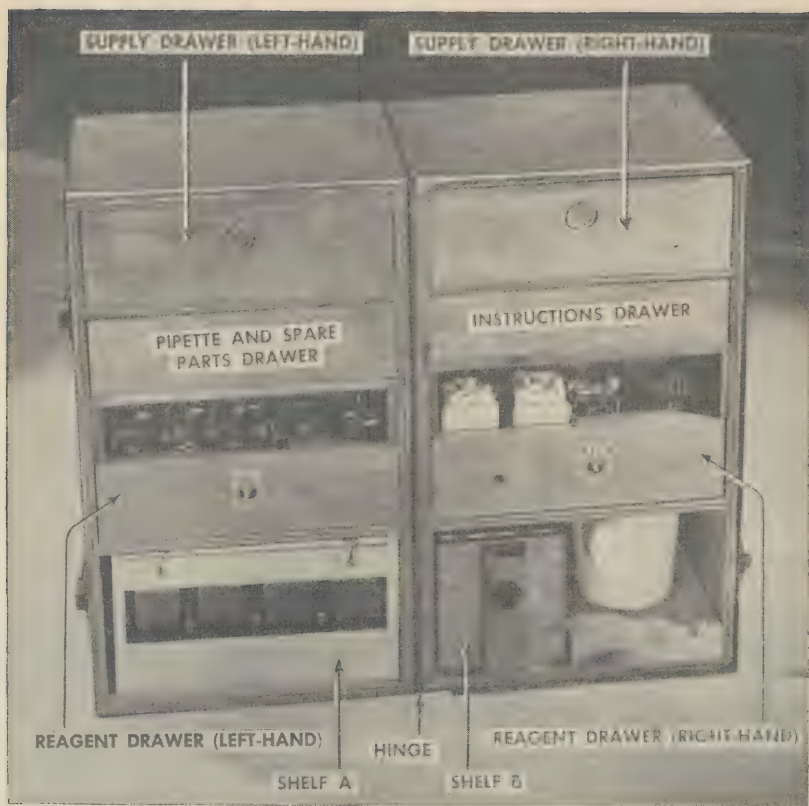


Figure 9. Field water-quality-control set, chest opened. Note drawer positions.

ment required. The standard solutions used with the set should be prepared before it is taken into the field.

b. TESTS. Tests made with the set may be divided roughly into three groups: routine control, salinity, and poisons. The routine control tests are for turbidity, pH, residual chlorine, and coagulation. The salinity tests are for chloride, alkalinity, soap hardness, and sulfate. The poison tests are for nitrogen mustard, arsenic, chlorine demand, and pH.

c. CHEST. The set is contained in a reinforced plywood chest fitted with two carrying handles and two holding-belt retainers for use in transportation. (See fig. 8.) Figure 9 shows the opened chest. Note the positions of the drawers and the packing of the bottom shelves.

Note. Each piece of equipment has its own position in the chest. After use, each article must be returned to its proper position.

(1) *Supply drawers* (fig. 10). The supply drawers hold the materials and equipment listed in table VIII. The right-hand drawer

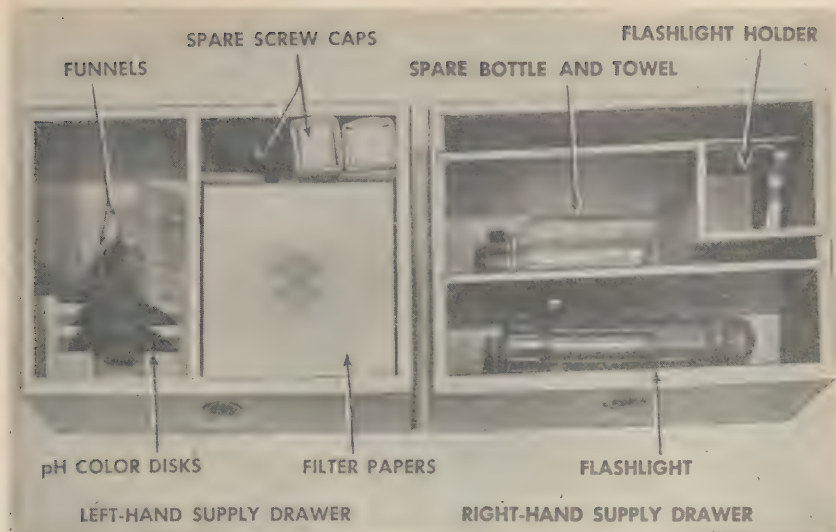


Figure 10. Supply drawers and contents.

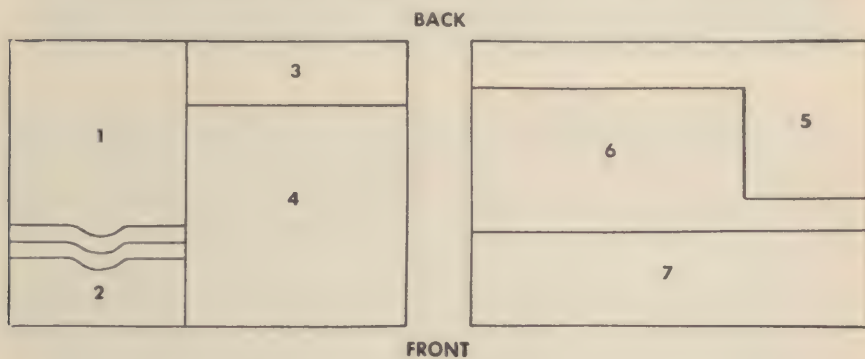


Table VIII. Contents of supply drawers

Left-hand supply drawer

Right-hand supply drawer

PLAN

| Compartment number | Item | Quantity | Figure number |
|--------------------------|---|----------|---------------|
| Left-hand supply drawer | | | 10 |
| 1 | Funnels | 2 | |
| | pH comparator tubes | 2 | |
| 2 | pH color disks | 2 | |
| 3 | Screw cap for 4-ounce solution bottle | 4 | |
| | Screw cap for 4-ounce narrow-mouth bottle | 2 | |
| | Screw cap for 8-ounce solution bottle | 2 | |
| | Screw cap for 8-ounce wide-mouth bottle | 4 | |
| 4 | Boxes of filter paper | 3 | |
| Right-hand supply drawer | | | 10 |
| 5 | Flashlight holder | 1 | |
| 6 | 8-ounce wide-mouth bottle | 1 | |
| | Towel | 1 | |
| 7 | Flashlight | 1 | |

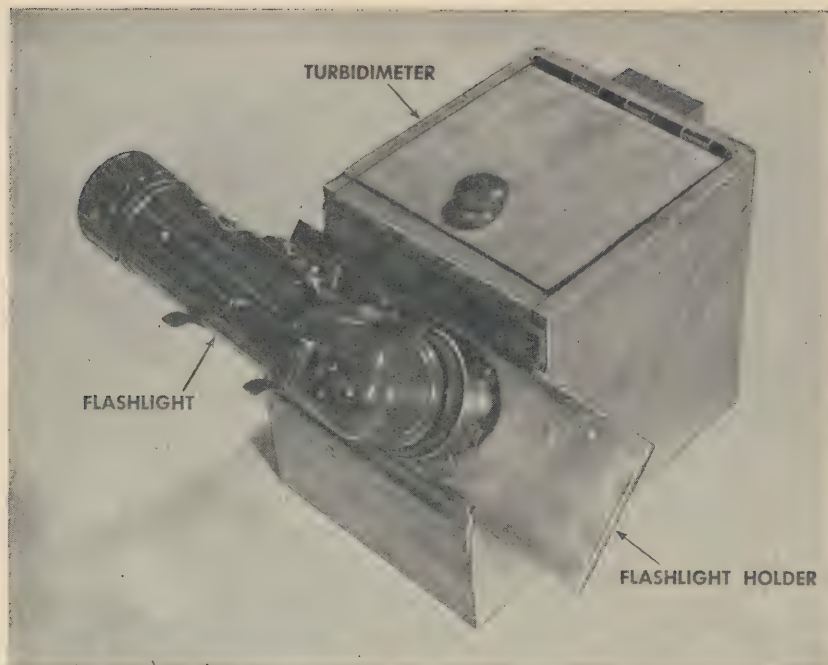


Figure 11. Flashlight and holder used with turbidimeter.

contains a flashlight holder and flashlight (fig. 11), which are used with the turbidimeter (*c*(4) (*b*) below) when there is no sunlight.

(2) *Pipette, spare-parts, and instruction drawers* (fig. 12). The pipette, spare-parts, and instructions drawers hold the equipment, materials, and printed instructions listed in table IX. The left-hand drawer holds the pipette tray. (See fig. 13.) Each pipette is graduated in fractions of a milliliter (ml). (See fig. 14.) Spare parts such as pipettes, pipette screw caps, and rubber bulbs are carried in the space under the pipette tray. The right-hand drawer is for this Technical Manual, loading plan of chest, and reference Technical Manuals.

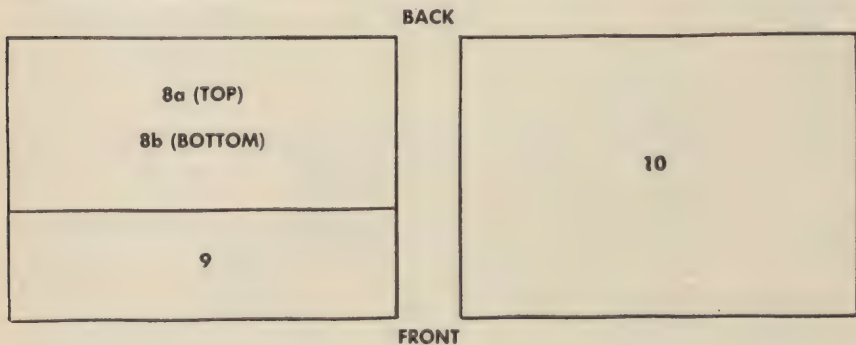


Table IX. Contents of pipette, spare-parts, and instructions drawers

Pipette and spare-parts drawer

Instructions drawer

PLAN

| Compartment number | Item | Quantity | Figure number |
|--------------------|--|----------|---------------|
| | Pipette and spare-parts drawer | | 12 |
| 8a | Dropper pipettes tray w/six 1-ml pipettes | 1 | 13 |
| 8b | Screw-cap dropper pipette (2-oz bottle) | 2 | |
| | Screw-cap dropper pipette (4-oz bottle) | 4 | |
| | Dropper pipette, 1-ml | 2 | |
| | Rubber bulbs (extra) | 6 | |
| 9 | Test-tube brushes | 2 | |
| | Instructions drawer | | 12 |
| 10 | Loading plan (folded) | 1 | |
| | TM5-295 (to be carried in drawer at all times) | 1 | |

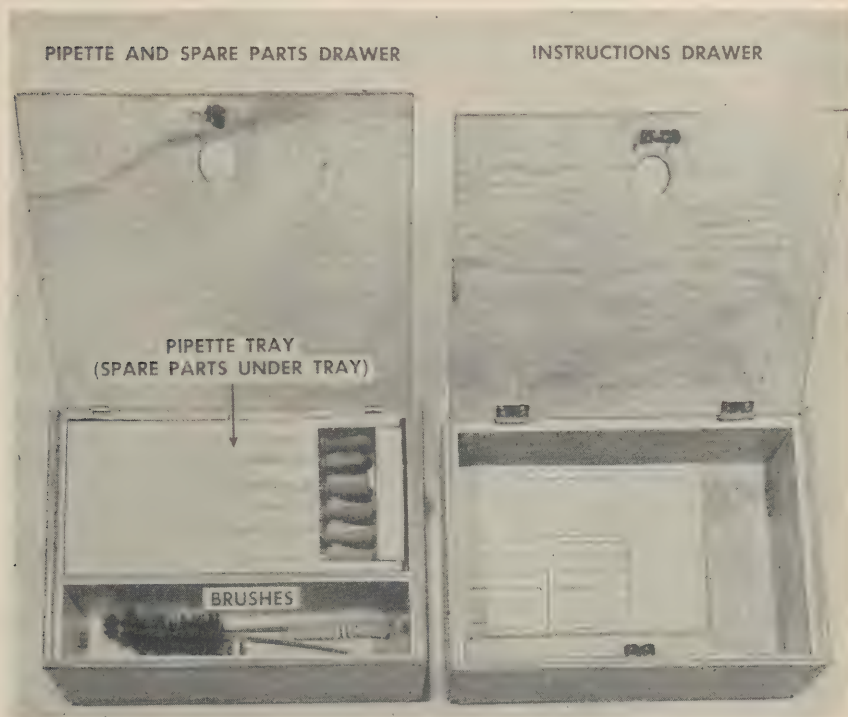


Figure 12. Drawers containing pipette, spare parts, and instructions.

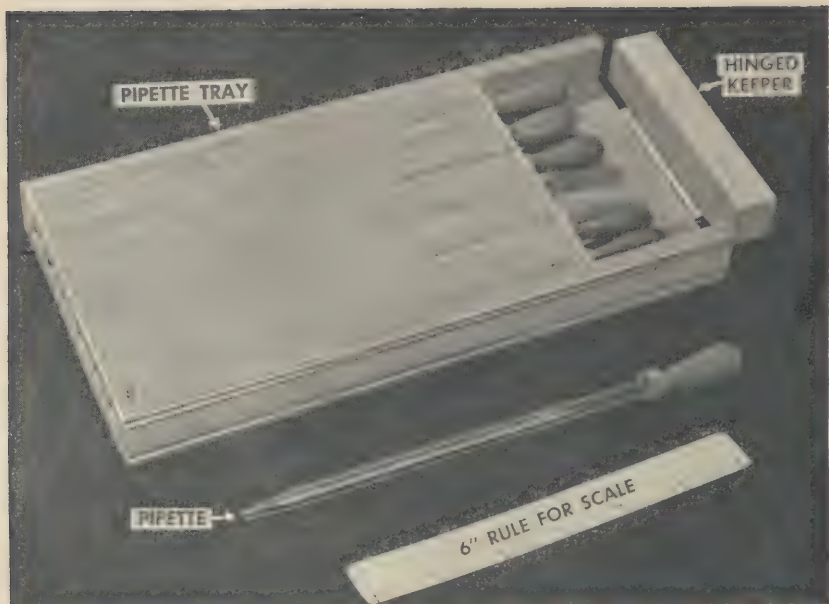


Figure 13. Pipette tray and pipettes. Each pipette has a labeled position.

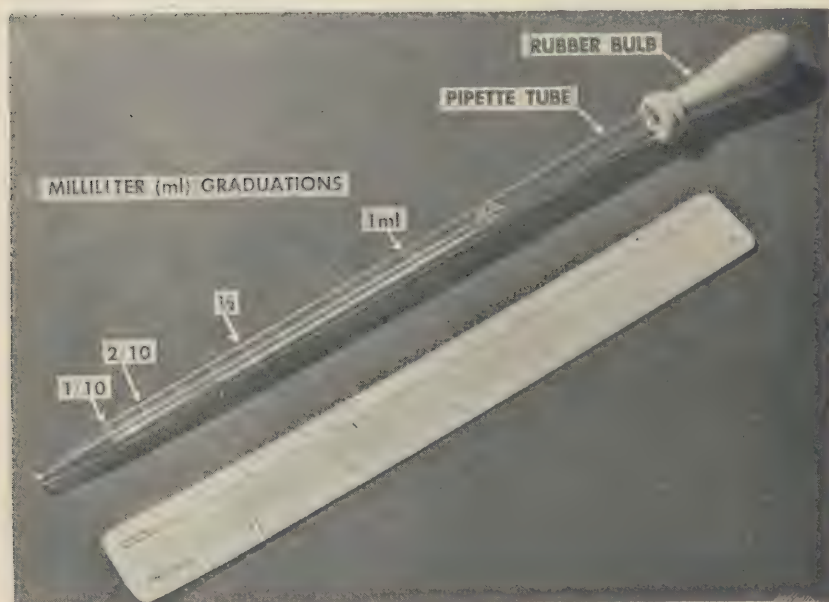


Figure 14. Graduations on pipette.

| | | | | |
|-----|-----|-----|-----|---------|
| 11 | 11 | 11 | 11 | 12 |
| 13a | 13b | 13c | 13d | 12 |
| 14a | 14b | 14c | 14d | 14e |
| 15a | 15b | 15c | 15d | 16a 16b |

| | | | |
|-----|-----|-----|-----|
| 17d | 17e | 17f | 17g |
| 17a | 17b | 17c | 18 |
| 19a | 19b | 20a | 20b |

Table X. Contents of reagent drawers
 Left-hand reagent drawer Right-hand reagent drawer
 PLAN

| Compartment number | Item | Quantity | Figure number |
|--------------------|---|----------|---------------|
| | Left-hand reagent drawer | | 15 |
| 11 | 4-ounce solution bottles (empty), <i>titrating</i> | 4 | |
| 12 | 4-ounce solution bottles (empty), <i>soap titrating</i> | 2 | |
| 13 | 4-ounce solution bottles, <i>indicator</i> : | | |
| 13a | Orthotolidin | 1 | |
| 13b | Bromthymol blue | 1 | |
| 13c | Bromcresol purple green | 1 | |
| 13d | Aqua purple | 1 | |
| 14 | 4-ounce narrow-mouth bottle: | | |
| 14a | Sulfuric acid | 1 | |
| 14b | Silver nitrate | 1 | |
| 14c | Soap | 1 | |
| 14d | Barium chloride | 1 | |
| 14e | Empty bottle | 1 | |
| 15 | 2-ounce bottle w/dropper: | | |
| 15a | Phenolphthalein | 1 | |
| 15b | Methyl orange | 1 | |
| 15c | Potassium chromate | 1 | |
| 15d | Empty bottle | 1 | |
| 16 | ½-ounce bottle w/dropper: | | |
| 16a | Aqua purple | 1 | |
| 16b | Bromcresol purple green | 1 | |
| | Right-hand reagent drawer | | 15 |
| 17 | 8-ounce solution bottles: | | |
| 17a | Sulfuric acid | 1 | |
| 17b | Soap | 1 | |
| 17c | Silver nitrate | 1 | |
| 17d | Barium chloride | 1 | |
| 17e | Turbidity | 1 | |
| 17f | Zeo-karb-na | 1 | |
| 17g | Sample bottle | 1 | |
| 18 | 25-ml graduate and holder | | |
| 19 | 8-ounce wide-mouth bottle: | | |
| 19a | Alum | 1 | |
| 19b | Soda ash | 1 | |
| 20 | 4-ounce solution bottles w/graduated dropper: | | |
| 20a | Alum solution | 1 | |
| 20b | Soda-ash solution | 1 | |

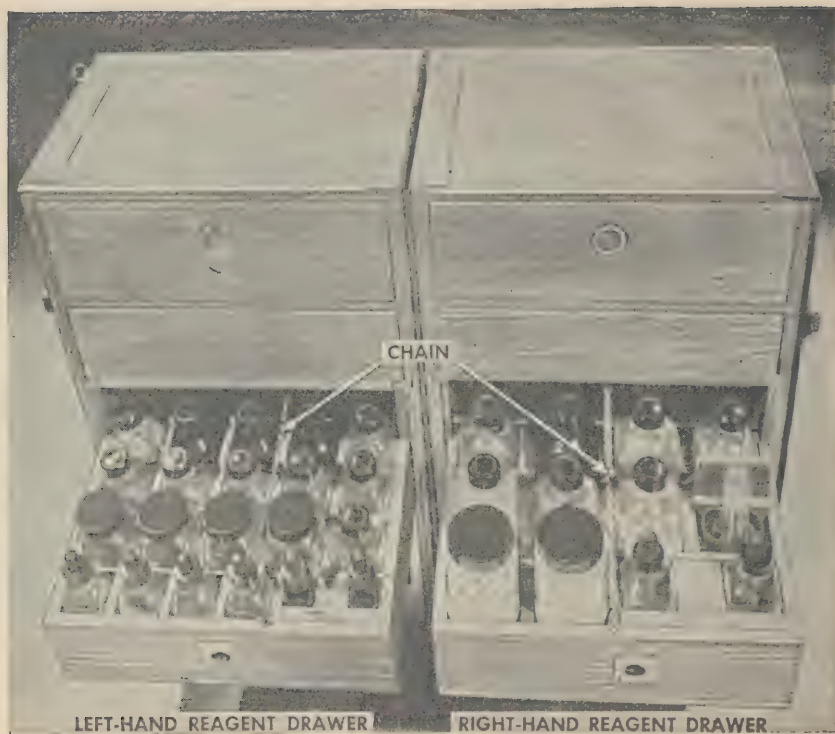


Figure 15. Reagent drawers.

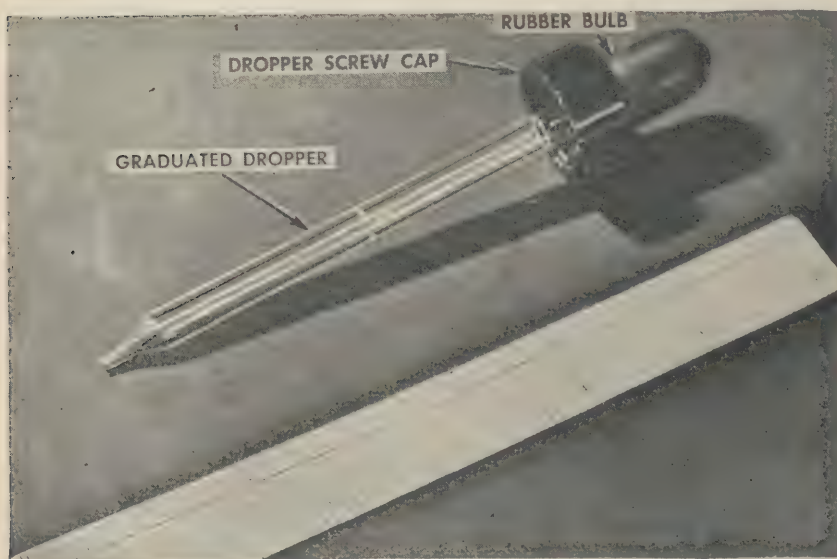


Figure 16. Graduated dropper with screw cap.

(3) *Reagent drawers* (fig. 15). The reagent drawers hold the materials and equipment listed in table X. These drawers are chained to prevent their being completely withdrawn from the chest. The chains should not be detached. A 25-ml graduate and holder (fig. 17) is in the right-hand reagent drawer.

(4) *Bottom shelves*. The bottom shelves hold the materials and equipment listed in table XI.

(a) *Left-hand shelf A*. The left-hand shelf A contains the following equipment and materials:

1. *Coagulation test set* (fig. 18) used in the coagulation test. (See par. 58.) It consist of four wide-mouth 8-ounce bottles in a wooden box.

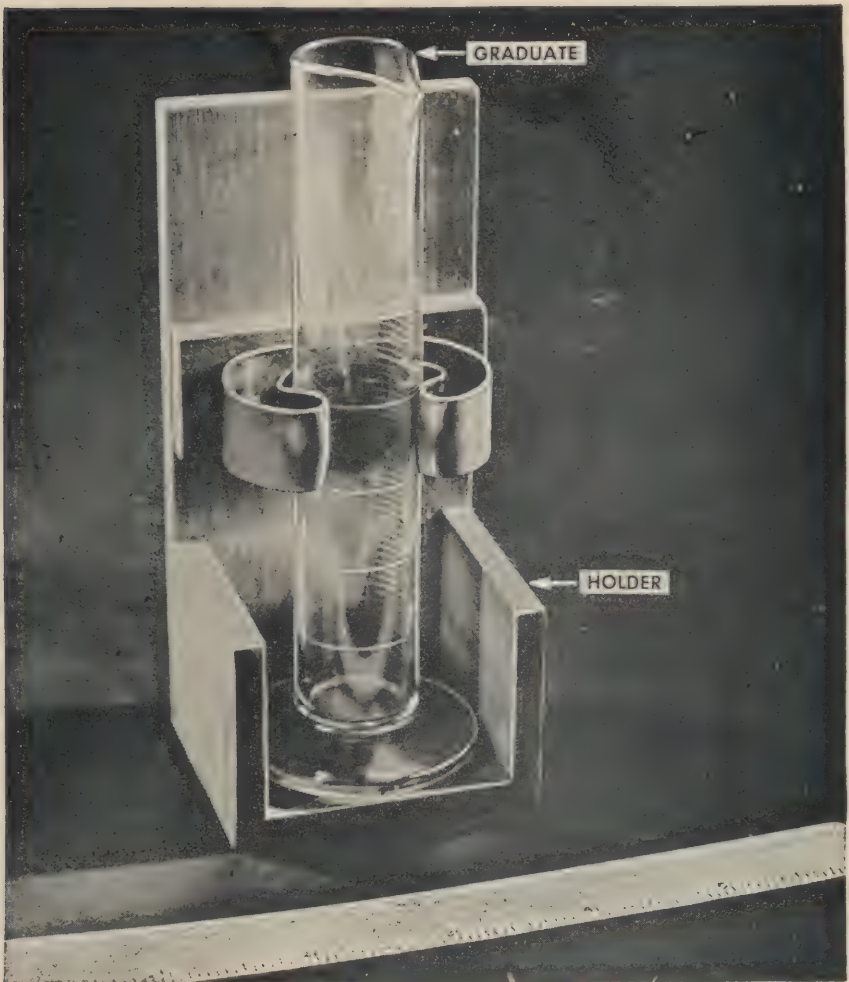
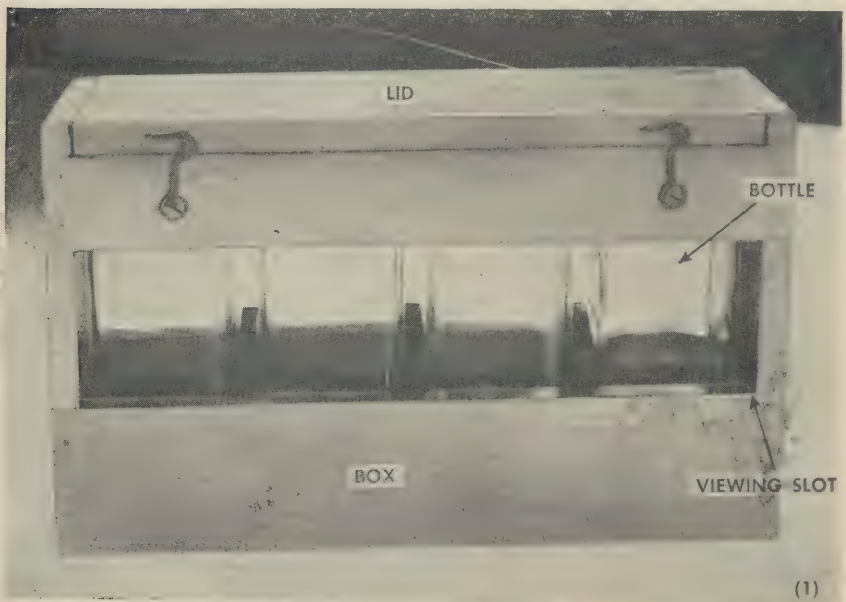


Figure 17. Twenty-five-ml graduate and holder.

2. *pH and chlorine comparator* (fig. 19) used in determining pH and amount of residual chlorine. (See par. 57.) It consists of a felt-lined fiberboard carrying case, chlorine color disks, the comparator, and two 1/2-ounce bottles with droppers. No comparator is supplied with the chest and the using unit must place its issue comparator in the space provided in the chest.
3. *Poison detecting set (kit, field, water-testing, screening, for chemical warfare agents)* (fig. 20) used in screening for poisonous substances in the water. (See par. 61.)

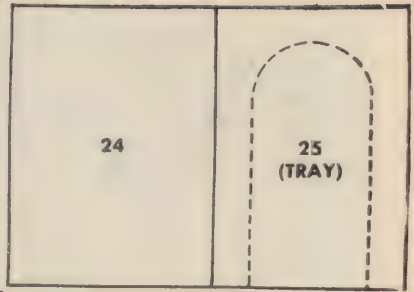
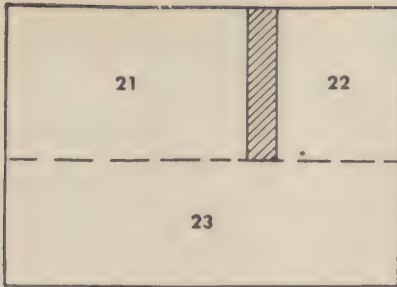
(b) *Right-hand shelf B.* The right-hand shelf *B* contains the following equipment:

1. *Porcelain measuring cup, 1-quart or 1,000-milliliter* (fig. 21) used to measure chemicals for coagulation. (See par. 58.) The cup is graduated on the inner face in ounces, quarts, and milliliters. A black spot on the bottom of the cup is used in making rough turbidity tests, as described in paragraph 60.
2. *Turbidimeter* (fig. 22) used to measure the turbidity of water. (See par. 60.) It consists of a wooden view-box holding four 4-ounce solution bottles.



① Set complete, showing slot for visual comparison.
Figure 18. Coagulation test set.

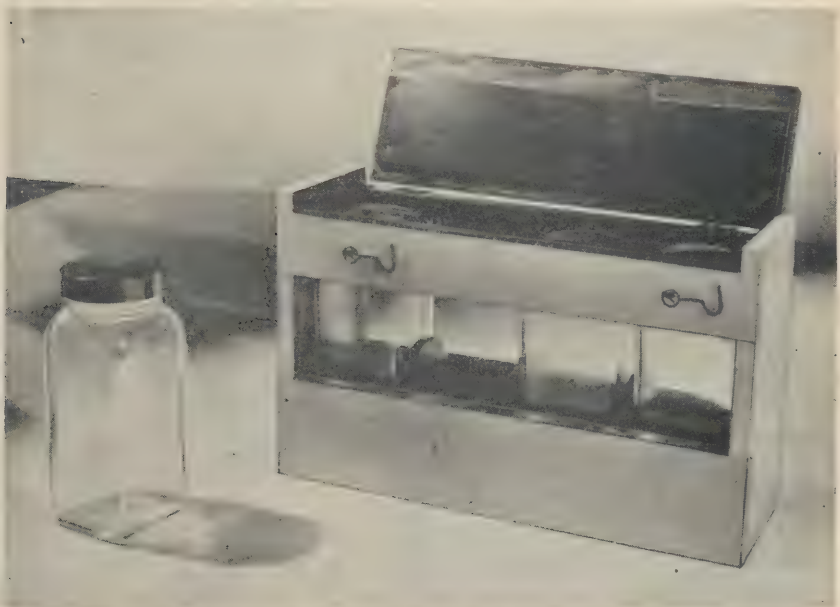
BACK



FRONT

Table XI. Contents of bottom shelves A and B
 Left-hand bottom shelf A Right-hand bottom shelf B
 PLAN

| Compartment number | Item | Quantity | Figure number |
|---------------------------|---|----------|---------------|
| Left-hand bottom shelf A | | | |
| 21 | pH and chlorine comparator | 1 | 19 |
| 22 | Poison test kit (kit, field, water-testing, screening, for chemical warfare agents) | 1 | 20 |
| 23 | Coagulation test set w/four 8-ounce wide-mouth bottles | 1 | 18 |
| Right-hand bottom shelf B | | | |
| 24 | Turbidimeter w/four 4-ounce solution bottles | 1 | 22 |
| 25 | Measuring cup, 1,000-ml | 1 | 21 |



② Box opened and one bottle removed. Interior of box is painted black.
 Figure 18. Coagulation test set (Contd.).

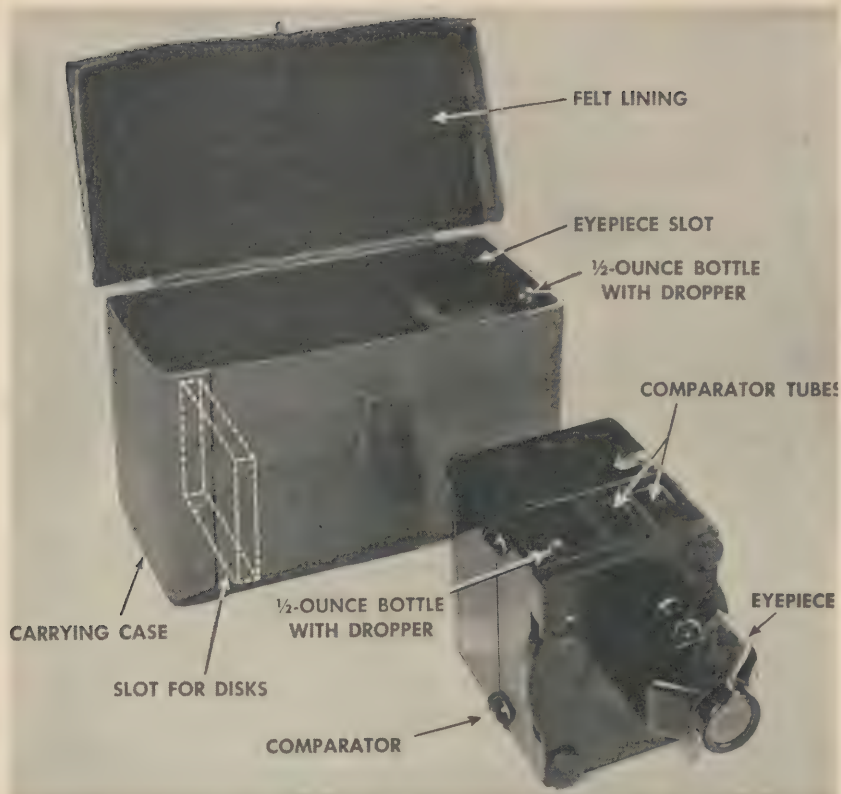


Figure 19. pH and chlorine comparator with case.

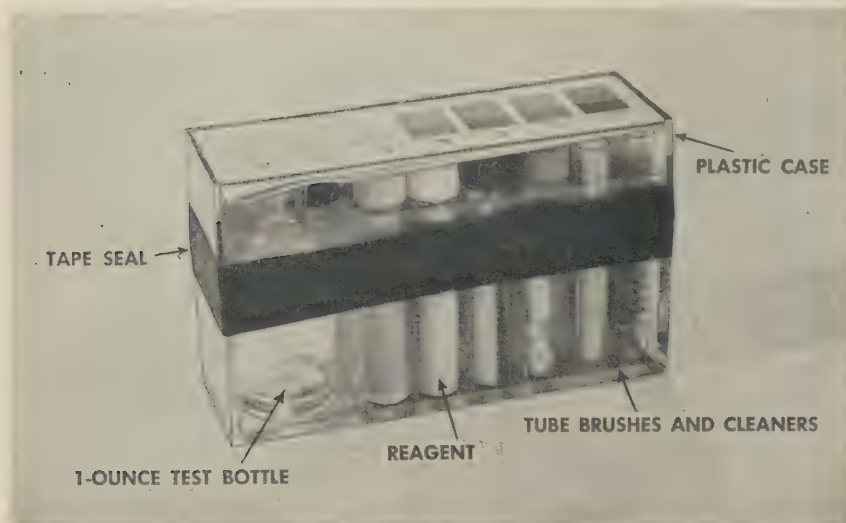
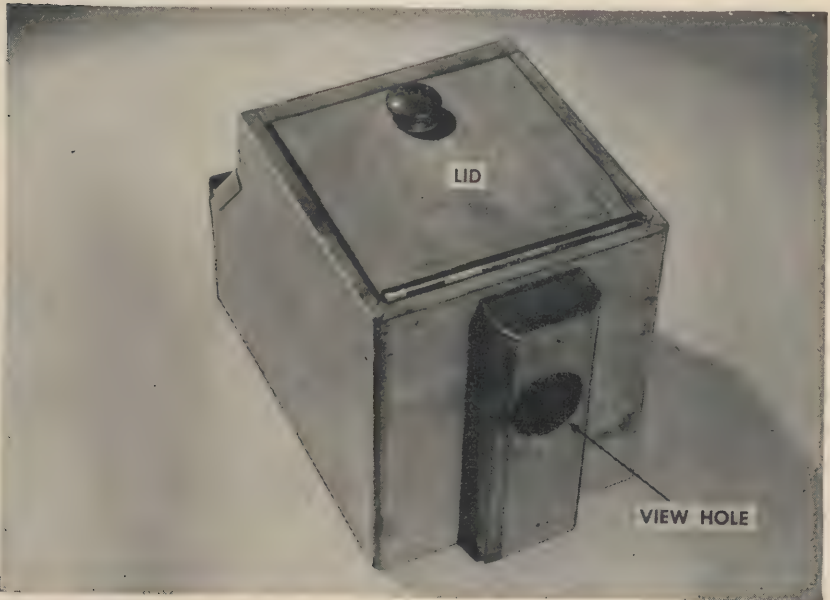


Figure 20. Poison detecting set kit, field, water-testing, screening, for chemical warfare agents.



Figure 21. Porcelain measuring cup, 1-quart or 1,000 milliliter. Note graduations in cup.



① Front view of turbidimeter ready for use, showing view hole.
Figure 22. Turbidimeter.



- (2) Rear view with lid up, showing unit with four bottles. Note light slot and flashlight-holder guide.

Figure 22. Turbidimeter (Contd.).

56. Units of Measurement

a. SYSTEM OF MEASURING CHEMICALS. (1) In water treatment, the weight of chemicals added to each gallon of water is such a small fraction of a pound that the grain is used as the unit of measure, quantities being expressed as grains per gallon. In larger chemical doses, quantities are expressed as pounds per million gallons. As there are 7,000 grains in each pound, 1 grain per gallon equals $1/7,000$ pound per gallon or 143 pounds per million gallons ($1/7,000 \times 1,000,000 = 143$). To obtain grains per gallon, divide the number of pounds per million gallons by 143.

(2) Another unit of weight per volume of water is parts per million (ppm). The unit is an abbreviation of the expression, "parts

by weight of substance per one million parts by weight of water." The word "part" refers to similar units and may be used to indicate any unit of measure. For example, 1 pound of alum per million pounds of water or 1 grain of alum per million grains of water both mean 1 ppm. However, water is not measured by weight so the weight of a gallon of water is used to convert pounds per million gallons to part per million. A gallon of water weighs 8.34 pounds so one million gallons weigh approximately 8,340,000 pounds. Therefore, 8.34 pounds per million gallons equals 1 ppm.

(3) Since 143 pounds per million gallons equals 1 grain per gallon and since 8.34 pounds per million gallons equals 1 ppm, 1 grain per gallon equals 143 divided by 8.34 or 17.1 ppm.

(4) Units of measurement and conversion factors are given below, each unit being multiplied by the proper factor to secure the desired value.

| To convert | To | | |
|----------------------------|-------------------|-------------------------|----------------------------|
| | Grains per gallon | Parts per million (ppm) | Pounds per million gallons |
| | Multiply by | | |
| Grains per gallon | 1 | 17.1 | 143.0 |
| Parts per million (ppm) | 0.058 | 1 | 8.34 |
| Pounds per million gallons | 0.007 | 0.12 | 1 |

(5) Dosages of coagulating chemicals are given as grains per gallon. Since 1 pound is equal to 7,000 grains, the dosage in pounds can be determined from the following equation:

Pounds of chemical required =

$$\frac{\text{gallons of water treated} \times \text{dosage in grains per gallon.}}{7,000}$$

Example: assuming 3,000 gallons of water to be treated with a dosage of 8 grains per gallon.

$$\text{Pounds of chemical required} = \frac{3,000 \times 8.0}{7,000}$$

$$= \frac{24,000}{7,000}$$

$$= 3 \frac{3}{7} \text{ pounds}$$

$$= 3 \text{ pounds } 7 \text{ ounces, approximately}$$

(6) For field approximations, 1 grain per gallon can be considered equal to one-eighth of a pound per 1,000 gallons.

b. RELATION BETWEEN PRESSURE AND HEAD. Each cubic foot of water weighs 62.4 pounds; therefore, water 1 foot deep produces a 62.4 pound per square foot pressure on the supporting surface, or 0.43 pounds per square inch (62.4 divided by 144). Thus, 1 pound per square inch (psi) pressure is produced by a column of water 1 square inch in area, and 2.32 feet high (1.0 divided by 0.43 equals 2.32). Therefore, a pressure of 1 pound per square inch is caused by a 2.32-foot *head*. The pressure in pounds per square inch is calculated by multiplying the head in feet by 0.43 or the head in feet is calculated by multiplying the pressure in pounds per square inch by 2.32.

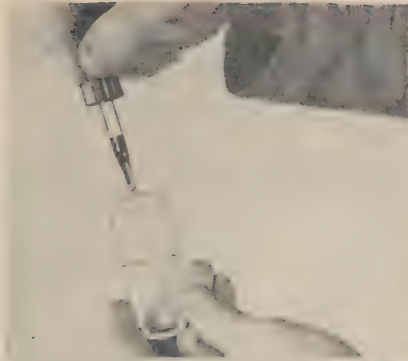
57. Residual-Chlorine and pH Determination

Residual-chlorine determinations are made to determine whether or not minimum residual in the water after a specified period of time is sufficient to disinfect water properly. The primary purpose of pH determination is to control coagulation since best flocculation is obtained at an optimum pH. Both residual-chlorine and pH determination tests are made with the color comparator.

a. USE OF COMPARATOR. (1) *General.* In the comparator (fig. 19), colored glasses imbedded in a plastic disk are used to determine residual chlorine and pH. By adding indicator solution, which changes color as the chlorine content or pH changes, to a sample of water of unknown residual-chlorine content or pH value and rotating the disk for residual-chlorine content or pH values so the colored glasses pass alongside the sample, the color of the sample and the glass in the disk can be matched. The chlorine content or pH value is read from the glass which most nearly matches the color of the sample.

(2) *Procedure.* To use the comparator, wash the two tubes to be used in the water to be tested. Fill the dropper to the graduated mark with indicator solution and add the solution to one of the tubes (fig. 23(1)); this equals $\frac{1}{2}$ ml. Fill the other tube to the etched mark with the water to be tested. Add the water from this second tube to the tube containing indicator solution (fig. 23(2)), thus mixing the indicator solution and the water to be tested. Refill the second tube to the etched mark with the sample to be tested. (See fig. 23(3).) Place both tubes in the comparator with the second tube behind the colored glass disk and the tube containing the indicator behind the viewing hole. (See fig. 23(4).) Then rotate the disk until the tube containing indicator and the colored glass in the disk are matched. (See fig. 23(5).) The value is then read directly. (See fig. 23(6).)

b. RESIDUAL-CHLORINE DETERMINATION. (1) Orthotolidine is the indicator solution used when determining residual chlorine



(1) PLACING INDICATOR SOLUTION IN CLEAN TUBE



(4) PLACING BOTH TUBES IN COMPARATOR INDICATOR SOLUTION ON LEFT



(2) ADDING WATER TO INDICATOR SOLUTION. TUBE IS FILLED UP TO ETCHED MARK



(5) OBTAINING READING FROM COMPARATOR BY ROTATING COLOR DISC TO MATCH COLOR OF INDICATOR SOLUTION



(3) A SECOND TUBE (ON RIGHT) HAS BEEN FILLED WITH SAMPLE OF WATER BEING TESTED. TUBE ON LEFT CONTAINS SOLUTION OF INDICATOR AND WATER OBTAINED IN STEP (2)



(6) pH VALUE IS READ DIRECTLY--pH OF THIS SAMPLE WAS 7.0. ALTHOUGH 7.0 IS NEUTRAL, IT IS NOT NECESSARILY PROPER pH VALUE AT WHICH TO ADD COAGULANTS. FOR PROPER FILTRATION OBTAIN OPTIMUM pH (PAR 58a)

Figure 23.

present in water. The color developed when this solution reacts with the residual-chlorine is matched against a standard color disk in the comparator. Readings on this standard color disk are given directly in parts per million, the maximum reading on the disk being 2 ppm.

(2) The time required for full development of color by orthotolidine depends on temperature and on the kind of residual chlorine (par. 41b(1)(d)) in the water. Because color development is several times slower near the freezing point than at 70° F. it is desirable to warm cold samples before adding orthotolidine to assure complete color development. This can be done by holding the sample tube in the fist. The rate of color development of active free chlorine in water is very rapid; full color development is usually completed within 1 minute. Color development is slower for the chloramines formed by combinations of ammonia and chlorine; at 70° F., 2 minutes are usually needed. For chloramines formed by chlorine and certain complex nitrogen compounds, full color development may require much longer periods. In standard tests, therefore, 5 minutes are allowed for color development and every effort is made to have water temperature above 50° F.

c. DETERMINATION OF PH. (1) *General*. Three indicator solutions are supplied for making pH determinations with the comparator. These indicators are bromcresol purple green, pH range 4.4 to 6.0; bromthymol blue, pH range 6.0 to 7.6; and aqua purple, pH range 7.6 to 9.2. Standard color disks covering the range of each indicator are supplied with the comparator. In general, the bromthymol blue indicator should be used first, since most pH values fall within its range. Readings for pH are made immediately after adding the indicator.

(2) *Checking pH readings beyond range of indicator*. When using the bromcresol purple green indicator readings at 5.8 or 6.0 should be checked on the bromthymol blue disk to make certain that the readings are not above the range of the lower disk. Likewise, pH readings of 7.6 and 7.8 on the aqua purple disk should be checked on the bromthymol blue disk. This check is necessary because most colorimetric indicators undergo a pronounced change over a short interval of the pH range, but once the end of this range has been reached, little change in color is noted even though a considerable change in pH takes place.

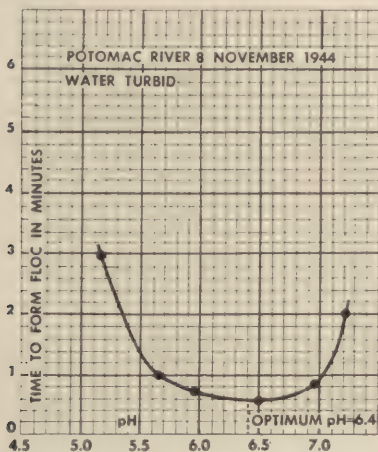
(3) *Methyl orange and phenolphthalein as pH indicators*. If the comparator is not available, the methyl orange and phenolphthalein indicators used in alkalinity determinations in the field water-quality-control set may be used to check water samples. Proceed as follows:

(a) To determine low pH above or below 4.3, fill a test bottle to the 50-ml mark with the water sample and add 2 drops of methyl orange indicator. Observe against a white background and interpret the color as: pinkish red, pH below 4.3; yellow, pH above 4.3.

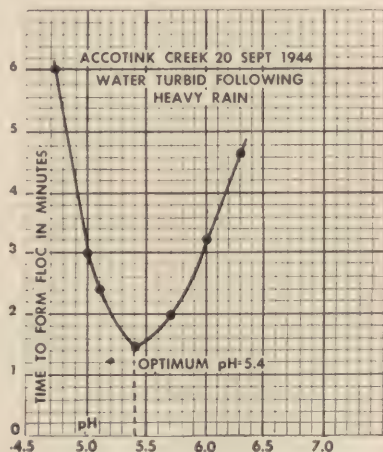
(b) To determine high pH above or below 8.3, fill a test bottle to the 50-ml mark with the sample and add two drops of phenolphthalein indicator. Observe against a white background and interpret as: pink pH above 8.3; colorless, pH below 8.3.

58. Coagulation Tests

a. GENERAL. The purpose of the coagulation test is to determine the optimum pH and the proper alum and soda-ash dosages for best flocculation. The optimum pH is that value of the pH which give the best flocculation and sedimentation. The optimum value varies considerably with the water being treated. *The pH of treated water should equal the optimum as determined in the coagulation test.* Figure 24(1) illustrates a pH curve obtained for Potomac River. Figure 24(2) illustrates a pH curve for Accotink Creek. It must be remembered that the optimum pH may be different on different days or times of day. Figure 24(1) indicates a water that has a broad pH curve, one that is generally easy to treat because a good floc may be obtained over a considerable range. Figure 24(2) indicates that a very precise adjustment will be required since the optimum pH is but one sharp point. Standard alum and soda-ash solutions are made up in the field using capsules which contain a measured amount of chemical. A solution of the same strength is obtained at every preparation.



① Curve for Potomac River water.



② Curve for Accotink Creek water.

Figure 24. pH curves.

The coagulation test is made with the coagulation test set shown in figure 18.

b. PREPARATION OF STANDARD SOLUTIONS. (1) Alum solution.

(a) Remove graduated dropper from alum bottle (compartment 20a) and insert funnel in empty bottle.

(b) Fill one of the empty bottles from the chest with clear potable water and have available for step (d).

(c) Open an alum capsule (compartment 19a) directly over funnel and squeeze or shake out all of the chemical possible. The transfer must be made with as little loss as possible.

(d) Wash alum from funnel with water selected in step (b). Wash capsule free of alum.

(e) Complete filling alum bottle with water after all alum has been washed into it.

(f) When refilling alum bottle after solution has been used, pour out any small portion left and rinse bottle before preparing new solution.

(2) *Soda-ash solution.* Prepare soda-ash solution exactly as alum solution, using soda-ash capsule and bottle from compartments 20b and a.

c. PROCEDURE FOR COAGULATION TEST. (1) Fill four bottles in the coagulation-test set with the raw water to be treated.

(2) Using the prepared alum solution, add different alum dosage to each of the four bottles. As a first trial add 2-, 3-, 4-, and 5-grain-per-gallon dosages. To add a dosage of 1 grain per gallon, fill dropper (fig. 16) to upper mark and force solution out down to lower mark. To add 2 grains per gallon, start at upper mark and empty dropper completely.

(3) Place bottles in holder and shake vigorously for 2 minutes.

(4) Hold coagulation-test set in the shade and look through bottles against light to determine if a satisfactory floc has formed. If satisfactory floc has formed, check pH of bottle, as in step (7) below. Floc is satisfactory if it has attracted any suspended turbidity so the water between the floc particles is clear and sparkling. It is not necessarily the largest floc, because large floc particles are likely to be light and will not settle well. When used with Army purification units, the floc must form and be visible to the unaided eye in less than 2 minutes.

(5) If satisfactory floc is not obtained in any sample, empty bottles and repeat test, using new raw water and 6-, 7-, 8-, and 9-grain-per-gallon dosages.

(6) (a) If alum alone does not produce a satisfactory floc, repeat test, using new raw water. Add same alum dosages as in (2) and (5), but in addition add half as great a dosage of soda-ash solutions.

Note. The soda-ash dosage giving the best floc formation is not necessarily fixed at one-half the alum dosage. More complete trial tests can be made by repeating the coagulation test with a fixed soda-ash dosage and varied alum dosages.

(b) Soda-ash and alum solutions are of equal strength so the dropper markings represent the same dosage in grains per gallon. For example, 2, 3, 4, and 5 grains per gallon of alum require 1, 1½, 2, and 2½ grains per gallon of soda ash respectively. Since the dropper is not marked in ½-grain-per-gallon dosages, estimate the midpoint between the upper and lower marks as closely as possible. To avoid confusion during dosing, the safest procedure is to mark the dosage necessary for each bottle on a piece of paper.

(7) Check pH (par. 57) of the water in the sample bottle which gives the best floc. If several dosages give good floc, select one of the lower dosages to save chemicals. Consider this pH and the corresponding alum or alum and soda-ash dosage to be optimum for flocculation.

d. MEASURING ALUM AND SODA-ASH DOSAGES REQUIRED FOR PRECOAGULATION OF 3,000 GALLONS OF WATER. (1) *Alum.* When a certain dosage of alum is desired in a tank of water, a definite amount of the chemical must be weighed. If no scale is available, the weight of alum is obtained by measuring the volume of water which the alum lumps replace. To do this, fill the white measuring cup to the 16-ounce mark, and add alum lumps to raise the water level. Alum is 1.6 times as heavy as the same volume of water. Therefore, when the water level is raised 10 ounces on the graduated scale of the cup, 16 ounces or 1 pound of alum have been added. Table XII gives the water levels in the cup after adding to an initial water level of 16 ounces, dosages of 1, 2, 3, and 4 grains per gallon for 3,000 gallons of water.

Table XII. Alum dosages and corresponding water levels in measuring cup.

| Alum dosage in 3,000 gallons of water (grains per gallon) | Water level in cup (oz) |
|--|----------------------------|
| 4 | 33 |
| 3 | 29 |
| 2 | 24.5 |
| 1 | 20 |
| Initial water level | 16 |

(2) *Measuring procedure.* Procedure for weighing alum in the measuring cup follows:

(a) Obtain optimum dosage of alum according to procedure for flocculation test in c above.

(b) Fill measuring cup to 16-ounce mark with water, as in figure 25.

(c) From table XII, determine height to which water level must

be raised to obtain desired dosage.

(d) Add lumps of alum until water reaches this level. *Make certain all alum lumps are below water surface when final level is checked.* Figure 25 shows the measurement of a 2-grain-per-gallon dosage of alum.

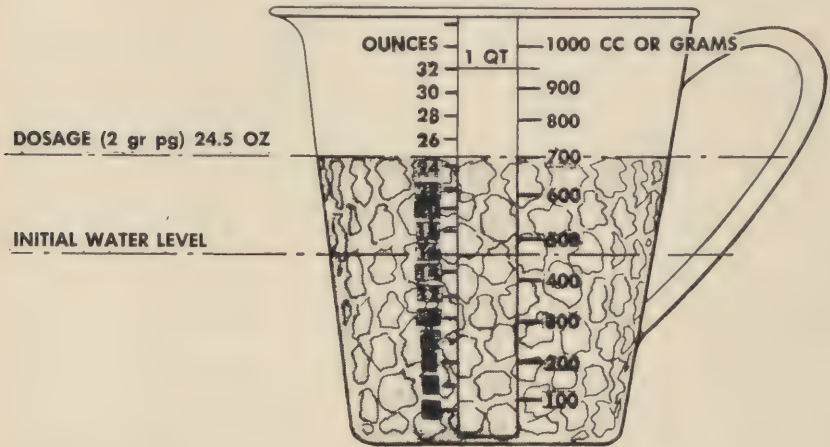


Figure 25. Measurement of 2-grain-per-gallon dosage of alum.

(e) Adjust dosage accordingly when treating more or less than 3,000 gallons of water. For dosages above 4 grains per gallon, make two separate measurements and add the two dosages together to obtain the higher value.

(3) *Soda ash.* There are two methods of measuring a soda-ash dosage.

(a) Four briquets of soda ash dissolved in 3,000 gallons give a dosage of approximately 1 grain per gallon.

(b) Broken pieces of briquets can be measured in the same way as alum. Soda ash is 2.4 times as heavy as the same volume of water. Therefore, when the water level is raised 6.4 ounces on the graduated scale of the cup, 16 ounces or 1 pound of soda ash have been added. Use table XIII to determine the height to which the water level must be raised to obtain the desired dosage.

Table XIII. Soda-ash dosages and corresponding water levels in measuring cup.

| Soda-ash dosage in 3,000 gallons of water (grains per gallon) | Water level in cup (oz) |
|--|----------------------------|
| 4 | 27.5 |
| 3 | 24.5 |
| 2 | 22 |
| 1 | 19 |
| Initial water level | 16 |

e. **EXPEDIENT COAGULATION TEST.** (1) *General.* If the field water-quality-control set is not available, an expedient jar test can be made using a series of jars, glasses, milk bottles, or similar containers. The containers used need not be the same size or shape but must contain the same amounts of water. It is suggested that one container be used to measure the water placed in all of the containers.

(2) *Preparing test solutions.* (a) Saturated solutions of alum and soda ash are made by withdrawing solutions from the chemical pots of chemical treatment units, or by dissolving a few crystals of alum in one small jar of water and a briquet of soda in another until no more crystals dissolve after vigorous stirring. In each case, leave a few undissolved crystals to be sure of saturation.

(b) The saturated solutions are too strong for use so *adjusted-strength solutions* must be formed. The desired alum solution is such that $\frac{1}{2}$ ml or cc when placed in approximately $\frac{1}{2}$ pint of raw water will lower the pH by between 0.2 and 0.3: for example, from 6.8 to 6.6 or 6.5. Diluting 1 part of the saturated alum solution with 10 parts of water usually produces approximately the desired strength. The desired soda-ash solution is such that the pH value will be raised between 0.2 and 0.3: for example, from 6.8 to 7.0 or 7.1. Diluting 1 part of the saturated soda-ash solution with 20 parts of water usually produces approximately the desired solution.

(3) *Test procedure.* The expedient coagulation test is performed as follows:

(a) Determine pH of the raw water.

(b) If pH is 6.4 or above and the water is practically colorless, place equal volumes of water in six jars. Add graduated increasing amounts of adjusted alum solution to each jar of water. As a start, add 1 ml or cc to the first jar, 2 to the second, 3 to the third, etc., for all the jars.

(c) Quickly stir all jars with a clean stick, but do not use more than two circular movements to mix the chemical and water. Continue stirring only enough to keep water barely moving for a period not less than 5 minutes.

Note. Violent stirring breaks up the floc and does not allow it to form into visible particles.

(d) Observe all jars while stirring and note the jar or jars in which the floc forms first. Record the stirring time at which the floc first becomes visible. If floc forms within 2 minutes after chemical solution is added, the result may be of value. Observe the characteristics of the floc and of the water between the particles after stirring has stopped. A clear, sparkling water between well-formed floc particles is satisfactory. However, for completeness the test should be continued until poor floc is obtained when in-

creased amounts of alum are added. A series of jars in which a good floc or series of good flocs is preceded and followed by a series jars having poor flocs indicates a complete test. Figure 5 shows a complete jar test.

(e) Determine the pH of the water in each jar to which alum solution was added. The pH value of the water in the jar having the best floc is the optimum pH. The pH values of all jars in which good floc has formed may be included within the pH range.

(f) In operating mobile or portable purification units, the chemical feed is adjusted so the pH of the effluent is at the optimum value as determined in the test. When batch treatment is used, the alum is introduced through the chemical basket. Dosage and pH must be checked when the tank is half full, and dosage adjusted so that when the tank is full, it is correct.

(g) If the pH value of the raw water is less than 6.4 ((a) above) or if the results of the jar test using alum alone indicate that the water has insufficient alkalinity, soda ash must be added. The series of jars are filled with raw water. A measured amount of adjusted soda-ash solution sufficient to raise the pH value to 7.6 is added to each jar. An additional 4 ml or cc are added to each jar and the adjusted alum solution is added. (See (b), (c), (d), and (e) above.)

(h) If an optimum pH has not been found or the floc takes too long to form, the test is repeated with increased amounts of soda ash and alum.

(i) When soda ash is added in the batch treatment, approximately the same ratio of soda ash to alum is used as in the jar test. In general, the optimum pH can be determined with alum alone. Soda ash should be used only when absolutely necessary.

59. Salinity Tests

a. GENERAL. (1) The four salinity tests made with the field water-quality-control kit are:

(a) The *soap-hardness test* is a measure of the total hardness, usually calcium and magnesium salts in the water. These substances produce hard waters which cause scale in boilers and automobile radiators.

(b) The *alkalinity test* indicates the amount of carbonates, bicarbonates, and hydroxides in the water.

(c) The *chloride test* measures the amount of chloride ions in the water, indirectly measuring the amount of sodium chloride or common salt present.

(d) The *sulfate test* is made to determine whether or not enough sulfate is present to produce undesirable physiological effects. The US Public Health Service Standards recommends 250 ppm as the

permissible limit of sulfate content. However, waters with much higher sulfate content can be and are consumed without adverse physiological effects. A low sulfate reading usually indicates low magnesium sulfate content.

(2) (a) Each of the four salinity tests serves to identify mineral characteristics of the water. When combined they give an estimate of the total dissolved solids, which is a basis commonly used for classifying waters as to mineral content. An approximation of the total dissolved solids is calculated as follows:

Total dissolved solids (ppm) = (ppm alkalinity) + (ppm sulfates X 1.4) + (ppm chlorides X 1.6)

Example: Salinity test of water

Alkalinity = 200 ppm

Sulfates = 100 ppm

Chlorides = 300 ppm

Total dissolved solids = $200 + (100 \times 1.4) + (300 \times 1.6)$

= $200 + 140 + 480$

= 820 ppm dissolved solids

(b) This method is based on certain assumptions and does not represent an exact calculation. Table XIV shows variations in the ground and surface waters used for drinking purposes in the United States. Results obtained on water being tested may be compared with these values to obtain an estimation of a satisfactory water.

(3) Two bottles of reagents, one small and one large, are provided for each test (compartments 14 and 17). As the solution is used up during the test, the small bottle is refilled from the larger bottle. The test bottles (compartment 11) in which the water sample is checked are in the left-hand reagent drawer. These bottles have two marks, the lower one at 50-ml capacity and the upper one at 100-ml capacity. The test solutions are measured with a pipette. (See fig. 14.) These pipettes deliver a total of 1-ml from the upper graduation mark and are calibrated in 1/10-ml divisions. *Each pipette is used only for the test for which it is marked in the pipette case and is returned directly to its place in the pipette case when the test is completed.* The pipette is conveniently manipulated by placing it in the palm of the right hand with the rubber bulb between the thumb and forefinger.

b. SOAP-HARDNESS TEST. (1) Fill the bottle marked "Hardness Testing Bottle" to the 50-ml mark with the water sample to be tested.

(2) Add soap solution to sample, recording amount added each time.

(a) Using the soap pipette, add 1/2-ml of soap solution to the water sample. Shake the bottle vigorously and place it on its side

Table XIV. *Approximate mineral content of various surface and ground waters in the United States*

| WELL WATERS USED AS CITY SUPPLIES ¹ | | | | | |
|--|------------------------|-------------------------------------|---------------|---------------------------------|----------------------------|
| City | Total dissolved solids | Total hardness (CaCO ₃) | Chloride (Cl) | Alkalinity (CaCO ₃) | Sulfate (SO ₄) |
| Pensacola, Fla. | 27 | 7 | 6 | 3 | 3 |
| Memphis, Tenn. | 87 | 39 | 2 | 66 | 4 |
| Savannah, Ga. | 180 | 120 | 6 | 114 | 7 |
| Long Beach, Calif. | 222 | 33 | 28 | 159 | 1 |
| Lincoln, Nebr. | 230 | 135 | 12 | 94 | 53 |
| Baton Rouge, La. | 260 | 3 | 6 | 202 | 11 |
| Enid, Okla. | 292 | 187 | 26 | 183 | 19 |
| Alexandria, La. | 298 | 5 | 20 | 196 | 4 |
| Madison, Wis. | 339 | 336 | 9 | 291 | 35 |
| Lansing, Mich. | 394 | 401 | 16 | 321 | 49 |
| Clarksdale, Miss. | 424 | 51 | 64 | 284 | 5 |
| Peoria, Ill. | 456 | 386 | 21 | 344 | 52 |
| Amarillo, Tex. | 514 | 305 | 20 | 381 | 63 |
| Sioux Falls, S. Dak. | 515 | 408 | 6 | 267 | 159 |
| Aurora, Ill. | 517 | 298 | 130 | 266 | 36 |
| Fort Dodge, Iowa. | 573 | 459 | 5 | 387 | 139 |
| Santa Monica, Calif. | 610 | 353 | 54 | 240 | 184 |
| Jamestown, N. Dak. | 780 | 362 | 40 | 356 | 241 |
| Sioux City, Iowa. | 792 | 548 | 10 | 316 | 298 |
| Galveston, Tex. | 825 | 68 | 299 | 298 | 0 |
| St. Augustine, Fla. | 947 | 520 | 225 | 143 | 291 |
| Galesburg, Ill. | 1,030 | 231 | 175 | 246 | 314 |
| Aberdeen, S. Dak. | 1,969 | 799 | 74 | 138 | 1,199 |

¹ From "The Industrial Utility of Public Water Supplies in the United States—1932," USGS Water Supply Paper, 658.² From "Composition of River and Lake Waters of the United States—1924," USGS Professional Paper, 133.³ From "Journal of American Public Health Association—Oct., 1913" and "Mineral Resources of the United States—1911, Part II."

SURFACE WATERS

| Source | Total dissolved solids | Total hardness (CaCO ₃) | Chloride (Cl) | Alkalinity (CaCO ₃) | Sulfate (SO ₄) | City water supply |
|-------------------------|------------------------|-------------------------------------|---------------|---------------------------------|----------------------------|---|
| Atlantic Ocean..... | 40, 100 | 4, 736 | 18, 885 | 143 | 3, 050 | |
| Great Salt Lake..... | 203, 490 | 23, 840 | 112, 896 | 305 | 13, 593 | |
| Lake Michigan..... | 157 | 125 | 4 | 120 | 12 | |
| Rainwater..... | 18 | 8 | 4 | 5 | 3 | Chicago, Ill. |
| Rivers: ² | | | | | | |
| Delaware..... | 70 | 43 | 3 | 38 | 12 | Philadelphia, Pa. |
| Hudson..... | 108 | 68 | 4 | 60 | 16 | Poughkeepsie, N. Y. |
| Potomac..... | 130 | 79 | 6 | 29 | 58 | Washington, D. C. |
| Mississippi..... | 202 | 139 | 9 | 106 | 43 | St. Louis, Mo. |
| Ohio..... | 207 | 110 | 22 | 37 | 72 | Louisville, Ky. |
| Rio Grande..... | 791 | 354 | 164 | 146 | 228 | Laredo, Tex. |
| Arkansas: Low flow..... | 1, 500 | 322 | 610 | 148 | 211 | Great variation in mineral content of water. Formerly used as water supply by Little Rock, Ark. |
| Average..... | 630 | 191 | 203 | 121 | 93 | Diluted with well water during period of low flow to reduce chloride content. |
| Saline..... | 2, 908 | 543 | 1, 012 | 265 | 479 | Not desirable as a city water supply. |
| Pecos..... | 3, 652 | 1, 778 | 944 | 69 | 1, 400 | Not desirable as a city water supply. |

WELL WATERS CONSIDERED UNSATISFACTORY FOR DRINKING PURPOSES³

| Source | Total dissolved solids | Total hardness (CaCO ₃) | Chloride (Cl) | Alkalinity (CaCO ₃) | Sulfate (SO ₄) | Remarks |
|---|------------------------|-------------------------------------|---------------|---------------------------------|----------------------------|---|
| "Alkali" Wells of North Dakota | 4, 590 | 1, 400 | 200 | 290 | 614 | Inhabitants living in region of these wells consider them unsatisfactory as a regular source of drinking water. |
| North Dakota | 3, 580 | 1, 880 | 95 | 410 | 978 | |
| North Dakota | 3, 940 | 2, 390 | 145 | 530 | 1, 344 | |
| North Dakota | 2, 870 | 1, 175 | 282 | 320 | 1, 737 | |
| Well Waters of Central Valley of California | 3, 600 | 910 | 1, 740 | 124 | 5 | Used as a domestic supply but later abandoned. |
| | 4, 100 | 1, 760 | 460 | 600 | 1, 640 | Used in cook wagon for a year but abandoned when better water was obtained. |
| California | 2, 900 | 1, 280 | 145 | 124 | 1, 680 | Owner of well did not consider it usable for soaking or drinking. |
| California | 2, 452 | 477 | 492 | 1, 604 | Trace | Inhabitants of region consider this water to be of poor quality. |

on a fixed surface. If no lather forms, continue adding soap solution in $\frac{1}{2}$ -ml portions, shaking the bottle and placing it on its side after each addition. As soon as a lather is obtained, allow the test bottle to remain *undisturbed* on its side until the surface of the lather begins to break enough so the water below shows plainly through the opening in the lather film or, if lather does not break, leave bottle untouched for 5 minutes. Unless the water is very soft, nearly all the soap bubbles disappear after the first addition of soap. As more soap is added, the break in the lather film becomes smaller and more time elapses before the break in the lather occurs.

(b) If the lather surface remains unbroken after 5 minutes, it is considered a permanent lather and the test is completed. Total the number of ml of soap required to obtain this lather and determine the hardness in ppm as follows:

$$\text{ppm hardness} = 50 \times (\text{total number of ml of soap solution required for permanent lather})$$

(3) If more than 6 ml of soap solution are required to obtain a permanent lather, the test is repeated with a new sample of water which has been diluted with equal parts of zero-hardness water. To do this, first measure 25 ml of the water to be tested in the graduated cylinder (fig. 17) and transfer it to the hardness-testing bottle. Next, pour 25 ml of zero-hardness water carefully from the top of the bottle to avoid losing any of the solid material. Add this portion to the water already in the testing bottle. Proceed with the test as outlined in (2) above and calculate ppm hardness as follows:

$$\text{ppm hardness} = 100 \times (\text{total number of ml of soap solution required for permanent lather})$$

(4) After using as much zero-hardness water as is needed for the test, refill the bottle with clear drinking water for future use before returning the bottle to the chest. If more zero-hardness water is needed to complete the tests, refill the bottle with clear drinking water and shake mildly for 10 minutes before using. The solid in the bottle will soften approximately forty 25-ml portions before becoming exhausted. To check the zero-hardness water, place 25 ml of it in the hardness-testing bottle and add $\frac{1}{2}$ ml of soap solution. If a 5-minute lather is not obtained, the chemical is considered exhausted. The chemical will soften very hard waters; however, the length of time it can be used is increased by refilling the bottle, after a part of it has been used, with a water known to be relatively soft. None of the zero-hardness water should be wasted.

(5) When an appreciable amount of magnesium is present, a false endpoint is often obtained before all of the hardness has reacted with the soap. To prove that the endpoint obtained is not false, $\frac{1}{2}$ ml of soap solution should be added after the first permanent lather is secured. If the lather resulting from the additional $\frac{1}{2}$ ml

of soap solution breaks up before the 5-minute period has elapsed, the first endpoint was false because of the presence of magnesium. The addition of soap is continued until a permanent lather is again obtained. The first endpoint is ignored in adding up the total amount of soap required for the test.

(6) A very small amount of soap is required to produce a lather in water having no hardness (distilled water). This amount, known as the lather factor, varies with the type of soap used. This factor is normally placed on the label of the soap reagent bottle. With the strength of soap solution used in the test set, the lather factor should not exceed a few tenths of milliliter. To obtain the correct soap hardness of the water, the milliliters of lather factor should be subtracted from the total milliliters of soap used before making the calculation for hardness.

c. ALKALINITY TEST. The alkalinity of water may be the total or methyl orange (MO) alkalinity, or the phenolphthalein alkalinity. Few surface or ground waters show phenolphthalein alkalinity. Nearly all except acid waters show MO alkalinity.

(1) *Methyl-orange alkalinity.* (a) Fill test bottle (compartment 11) to the 50-ml mark with water sample to be tested.

(b) Add 2 drops of methyl orange indicator solution. Place test bottle over a white towel or other white surface so a change in the solution's color can be seen easily.

(c) Add sulfuric-acid solution with sulfuric-acid pipette until test sample begins to turn from a yellow to a pinkish red color. Record total number of ml of sulfuric-acid solution used.

(d) The ppm of MO alkalinity are calculated as follows:

$$\text{ppm MO alkalinity} = 100 \times (\text{total number of ml of sulfuric acid required})$$

Sample calculation :

50-ml water sample ; ml of sulfuric acid required

$$\begin{array}{r} 1 \text{ ml} \\ 1 \text{ ml} \\ 0.5 \text{ ml} \\ \hline 2.5 \text{ ml} \end{array}$$

$$\text{ppm MO alkalinity} = 100 \times 2.5 = 250 \text{ ppm}$$

(2) *Phenolphthalein alkalinity.* (a) Fill test bottle (compartment 11) to 50-ml mark with water sample to be tested.

(b) Add two drops of phenolphthalein-indicator solution. Place over a white surface as in previous test. If no color forms in sample, record value of phenolphthalein alkalinity as zero.

(c) If a pink color forms in solution, test sample by adding sulfuric-acid solution a drop at a time until pink color just disappears. Record total number of ml of sulfuric acid used.

(d) The ppm of phenolphthalein alkalinity is calculated as follows:

$$\text{ppm phenolphthalein alkalinity} = 100 \times \frac{\text{total number of ml of sulfuric acid required}}{\text{total number of ml of sample}}$$

d. TEST FOR CHLORIDES. (1) Fill a test bottle (compartment 11) to the 50-ml mark with water sample.

(2) Add three drops of potassium chromate (yellow) indicator solution.

(3) Add silver-nitrate solution with silver-nitrate pipette until sample being tested begins to change from a yellow to a definite red-
ish color. Give water sample a mild agitation after each addition of silver-nitrate solution by rotating bottle back and forth. Record total number of ml of silver nitrate used.

(4) The chlorides in terms of the chloride radical (Cl) are calculated as follows:

$$\text{ppm chlorides} = 100 \times \frac{\text{total number of ml of silver nitrate required}}{\text{total number of ml of sample}}$$

Sample calculation:

50-ml water sample; ml of silver nitrate required

1 ml

1 ml

0.3 ml

2.3 ml

$$\text{ppm chlorides} = 100 \times 2.3 = 230 \text{ ppm}$$

e. TEST FOR SULFATES. (1) The sulfate value is found by trial, the test merely determining approximate values. For this reason, it may be necessary to repeat the test several times.

(2) The test is begun by testing for sulfates at 100 ppm as follows:

(a) Fill a clean test bottle (compartment 11) to the 100-ml mark with the water to be tested.

(b) Add 1 ml of barium-chloride solution with the barium-chloride pipette to the sample. Shake intermittently for 10 minutes.

(c) Tear a piece of filter paper in small pieces. Place them in solution.

(d) Shake for 5 minutes or until paper becomes fluffy and gelatinous.

(e) Place a funnel and filter paper in a second bottle from compartment 11. To place the filter paper in the funnel, first fold it in half and then into quarters. (See fig. 26.) Insert the paper into the funnel, completely lining the cone of the funnel.

(f) Filter about one-fourth of the sample into the second bottle. Rinse the second bottle with this small portion of filtrate and discard the filtrate. Replace the funnel and continue filtration, collecting about one-half bottle (50 ml) of filtrate.

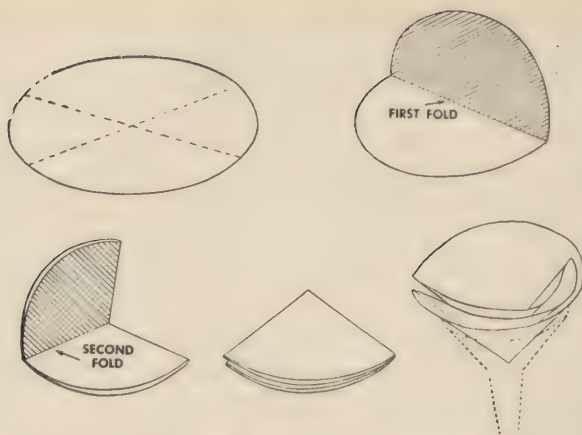


Figure 26. Folding filter paper for use in funnel.

(g) Add 1 ml of barium-chloride solution to the filtrate with the barium-chloride pipette, shake for 5 seconds, and observe immediately for a precipitate or a clear solution.

(3) If a clear solution is obtained from (2) above, record the sulfates as less than 100 ppm; if an immediate precipitate or milky solution is obtained, the sulfates are greater than 100 ppm and a new sample must be tested for 200-ppm sulfate. This test is performed as in (2) except that in step (b), 2 ml of barium-chloride solution are added. For each succeeding test, add 1 ml of barium-chloride solution for each additional 100-ppm sulfate. Therefore, to test for 300-ppm sulfate, 3 ml of barium-chloride solution are added. Note that the 1 ml of barium-chloride solution added after filtration ((2) (g) above) is *not changed*.

(4) If a clear solution is obtained, the sulfates are less than the ppm tested for and the sulfates are recorded as between the value of the test and that of the preceding test. If an immediate precipitate or milky solution is obtained, the sulfates are greater than the ppm tested for and a new sample must be tested for the next higher value.

60. Turbidity Tests

a. GENERAL. Turbidity measurement shows the extent to which suspended matter is present in raw water or has been removed from treated water. There are two types of turbidity test. The first type uses the turbidimeter (fig. 22) and standard turbidity solutions. The second type uses the white porcelain cup with its black enameled spot for approximate but very rapid turbidity readings.

b. PREPARATION OF TURBIDITY STANDARDS. (1) *Preparation of*

turbidity-free water. Turbidity standards are prepared by using turbidity-free water and adding to it a known amount of standard turbidity solution. Water which appears clear to the eye may still contain several ppm of turbidity which must be removed before making up the turbidity standards. To prepare turbidity-free water, proceed as follows:

(a) Fill square 8-ounce bottle from right-hand supply drawer and a similar bottle from coagulation test set with clear drinking water.

(b) To each bottle, add piece of filter paper which has been torn into about 10 or 15 small pieces.

(c) Shake each bottle intermittently for about 10 minutes. Filter paper will become fluffy and gelatinous.

(d) Add 1 ml of alum solution (1 dropperful equals 1 ml) to each bottle and shake for about 5 minutes.

(e) Place a funnel and filter paper in two of the round bottles in turbidimeter. Make certain bottles are clean.

(f) Filter about one-fourth of each bottle, remove funnel, rinse bottle with filtered water, and discard this water. Replace funnel and continue filtering until each bottle is full to the neck. Seal immediately with screw cap to keep dust out of sample and mark as "O" with wax pencil.

(2) *Preparation of 3-ppm turbidity standard.* To the second bottle of turbidity-free water prepared in (1) above add 3ml of a standard turbidity solution from the stock solution bottle. *Thoroughly shake the stock turbidity solution immediately before using any part of it.* Not more than 1 minute should elapse between shaking the solution and withdrawing the necessary number of milliliters. Mark the bottle "3" with wax pencil.

(3) *Preparation of other turbidity standards.* If the operator is not familiar with the use of the turbidimeter, practice standards of 1 ppm and 10 ppm should be made. The 1-ppm standard requires 1 ml of stock solution and the 10-ppm standard, 10 ml of stock solution. Compare various combinations of the standards in the turbidimeter. Low turbidity standards keep for only a short time. *New standards should be prepared weekly.* Under ideal conditions at least four standards would be made available for comparison with the water samples, but the quantity of stock turbidity solution and the number of bottles in the set do not permit such a complete comparison. For this reason, two standards are recommended for routine readings, a 0-ppm and a 3-ppm standard. The 3-ppm standard is considered most useful when only one standard is prepared.

c. **USE OF TURBIDIMETER.** Place the standard and the sample to be compared in the turbidimeter next to the light opening, as in figure 27. Remove the other bottles from the turbidimeter when

making comparisons. Wipe each bottle clean before placing it in the turbidimeter. Place the eye close to the port in the back of the box to view the samples and point the opening in front toward the sun. For night or indoor comparisons, use the flashlight and holder shown in figure 11. In direct light rays, the suspended particles will sparkle and the path of the rays can be plainly seen. Under cloudy skies, the suspended particles give a milky white color to the sample. Water having no turbidity will not show light rays or milky color.

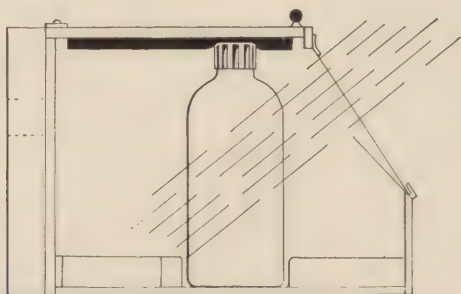


Figure 27. Light rays and position of sample bottles in using turbidimeter.

d. PROCEDURE FOR ROUTINE TURBIDITY TESTING. (1) Collect sample to be tested in one of the empty turbidity bottles. Both water sample and standard bottle must be clean.

(2) Place the sample and zero standard in turbidimeter, as in *c* above. This comparison gives observer the contrast between a sample in which turbidity is present and one in which it is absent.

(3) Replace zero standard with 3-ppm standard. Record the turbidity as less than, equal to, or greater than 3 ppm.

e. USING MEASURING CUP FOR TURBIDITY DETERMINATION. (1) In checking low turbidities, such as the effluent from a purification unit, fill the measuring cup with about $\frac{1}{2}$ inch of water to be tested and note black spot. Fill the cup and observe again. If the spot is still as black as it was originally, a reasonably low turbidity (below 5 ppm) is being attained. Turbidities above 5 ppm will produce a graying or milky hue in the black spot.

(2) Since no turbidimeter is provided for use on surface waters, the measuring cup can be used to determine whether a surface water has more or less than 100-ppm turbidity. The procedure follows:

(a) Fill cup to top with water.

(b) If black spot disappears from sight, turbidity is 100 ppm or over.

(c) If outline of black spot is still visible, turbidity is less than 100 ppm.

f. STOCK SOLUTION. If the standard stock solution is shaken well before any solution is withdrawn, it will remain at approximately the same strength. It is recommended that the solution be discarded when only about 1 inch is left.

61. Poison Tests

a. GENERAL. The poison tests are used to detect sources of water so contaminated with chemical warfare agents that they cannot be made potable by ordinary field treatment methods. The tests are performed with the kit, field, water-testing, screening, for chemical warfare agents. The following precautions should be taken when using the kit:

(1) Samples of water for these tests must be taken directly from the source in question.

(2) Tests should not be made on water which has already been put through purification units, since chemical reactions during treatment may give false results.

(3) If water sources are contaminated, a source giving a satis-

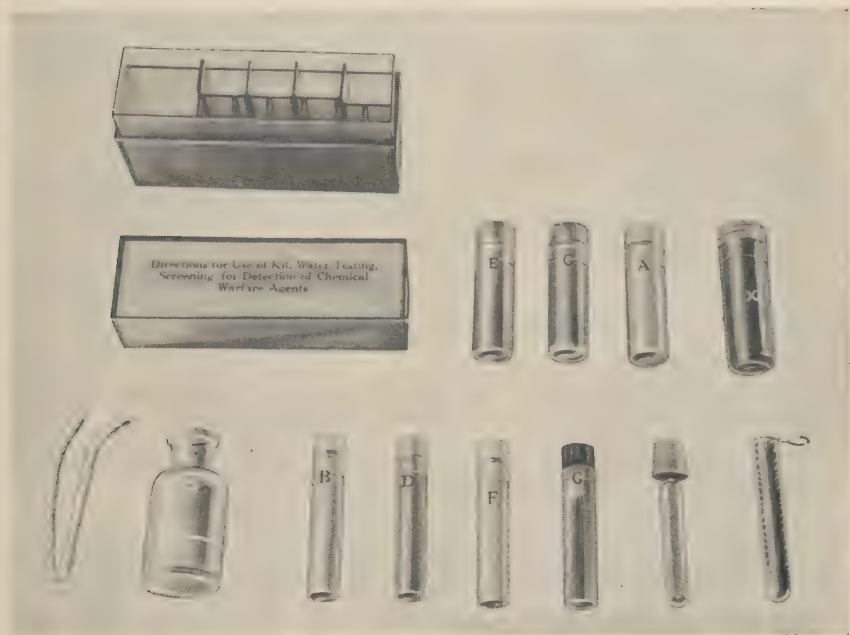


Figure 28. Contents of water testing kit (kit, field, water-testing, screening, for chemical warfare agents). Vial E, RB tablets; vial C, zinc pellets; vial A, KHSO_4 tablets; vial X, orthotolidin testing tablets; pipe cleaners; pot P, for arsenic test; vial B, arsenic test papers; vial D, RA tablets; vial F, water purification tablets; vial G, nitrazine strips for pH test; tube H with stopper in test tube; test tube with wire brush; color chart in directions posted in top.

factory test must be found, or permission must be obtained from a qualified officer to treat the contaminated source.

(4) When determining pH and chlorine demand, do not use nitrazine paper if the pH and chlorine comparator is available.

(5) A pH less than 6.0 is cause for suspicion, since nearly all natural waters have a pH well above 6.0. However, highly colored swamp waters may have a pH below 6.0. In this case, a considerable drop from the normal should be considered suspicious.

(6) A chlorine demand greater than 5 ppm is cause for suspicion. However, dissolved vegetable matter may show a higher chlorine demand.

b. PROCEDURES FOR TESTS. (1) General directions. Before using the kit, read the directions thoroughly. The directions for use are also contained in the kit and each item is identified as shown in figure 28. Obtain water sample in canteen cup or similar container, disturbing water source as little as possible. Start the arsenic test first and while it is developing carry out the other tests.

(2) *Arsenic test.* The procedure for conducting the test for lewisite and other agents containing arsenic is as follows:

(a) Fill pot *P* (fig. 28) up to mark with water to be tested.

(b) Place two pellets from vial *A* (fig. 28) into the pot; shake to dissolve.

(c) From vial *B* (fig. 28) take a test strip by the top end. Carefully insert the strip into tube *H* as shown in figure 29. Bend the strip near the top so it remains in tube with bent end hanging over the edge of the tube. In handling the strip, touch only the top end and keep the strip dry.

(d) When the pellets added in step (b) have dissolved, add five pellets from vial *C* (fig. 28) to the contents of the pot.

(e) Promptly fit the test-paper assembly (step (c)) into the pot, as indicated in figure 29, so the gases released rise up past the test paper.

(f) If the pot is cold, warm it with the hand. Allow the test-paper assembly to remain in the pot for 20 minutes.

(g) Remove the test strip and note the length of the resulting yellow or brown stain. A stain of $\frac{1}{4}$ inch or more indicates a positive test; a stain less than $\frac{1}{4}$ inch indicates a negative one.

(3) *Turbidity and color.* Fill test tube with water to be tested and note presence or absence of turbidity and color. However, turbidity and color alone in the sample are not conclusive evidence of the presence of chemical agents. Continue the test.

(4) *pH test.* Dip a strip of nitrazene test paper into the water and compare the resulting color of the paper with the color chart. A pH well below 6.0 indicates possible contamination. If a chlorine



Figure 29. Arsenic-test assembly. Note arsenic test paper, tube H, and pot P.

comparator is available, use it to determine pH.

(5) *Mustards test*. This test determines the presence or absence of mustard, nitrogen mustard, and cyanogen chloride.

(a) Rinse test tube with water to be tested and carefully fill it $\frac{1}{2}$ inch deep with the suspected water.

(b) Add one tablet from vial D. (See fig. 28.)

(c) Shake for at least 3 minutes to break up tablet; allow to stand for 5 minutes.

(d) During cold weather, warm tube in hand for additional 5 minutes.

Note. Yellow color after (c) or (d) is positive test for cyanogen chloride.

(e) Break one tablet from vial E (fig. 28) in half and add *both halves* to the water being tested. Shake the test tube until tablet is dissolved. While shaking, watch for the development of any color.

(f) Observe tube for $\frac{1}{2}$ minute against white background.

(g) Even a slight blue or red color (mainly in curd form) indicates a positive test for mustard or nitrogen mustard.

(h) A yellow color indicates cyanogen chloride. In heavy pollutions, the yellow color appears before step (e). White or light gray color indicates a negative test.

(i) The test detects nitrogen mustards in concentrations of 5.0 ppm or greater. Concentrations less than 5.0 ppm may affect some consumers and complete reliance cannot be placed on this test alone. A more comprehensive kit, the Medical Department kit, water-testing, poisons, treatment-control, permits qualitative analysis of water and will detect nitrogen mustards in concentrations below 5.0 ppm.

(6) *Chlorine demand test.* Chlorine does not neutralize poisonous chemical agents in water. However, it may reveal the presence of certain chemical warfare agents which react very quickly with chlorine and immediately increase the chlorine demand of the water. When a chlorine dosage of 6.0 ppm fails to leave a residual of at least 1.0 ppm *after 2 minutes contact time*, chemical warfare agents may be present. The test is conducted as follows:

(a) Fill a canteen with water to within 1 inch of top.

(b) Add three water purification (halazone) tablets from vial F. (See fig. 28.) Place the cap on the canteen and shake until the tablets dissolve. This should occur between 2 and 5 minutes.

(c) Five minutes after tablets have dissolved, transfer treated water from canteen to plastic tube with yellow band. This is vial X. (See fig. 28.) The tube is filled to the bottom of the yellow band.

(d) Add one tablet from vial X; shake and note color when dissolved.

(e) A positive test is indicated by no color or a color lighter than the yellow band in the plastic tube.

(f) A negative test is indicated by an orange color or color as deep as the yellow band.

(g) When available use a chlorine comparator. In using the comparator, substitute the solution from the canteen for the tube containing indicator solution. A positive test is indicated by a residual of less than 1.0 ppm, meaning chlorine demand is greater than 5. A negative test is indicated by a residual of 1.0 ppm or greater.

(7) *Taste and odor.* If the tests for color and turbidity, arsenic, mustards, and chlorine demand are all negative, *carefully* smell and taste the suspected water.

(a) A positive test is indicated by an odor that makes the eyes smart or the nose sting; by a biting, peppery, or strongly objectionable taste; or by any taste or odor of a known war gas.

(b) Absence of taste or odor indicates a negative test, but does not necessarily mean water is safe. A negative test is also indicated if the only odors and tastes are those normally characteristic of natural water.

c. INTERPRETATION OF TESTS. (1) Water is considered con-

taminated and unsafe if one or more of the tests gives the results indicated below:

| | |
|----------------------|--------------|
| Arsenic test | Positive |
| pH test | pH below 6.0 |
| Mustard test | Positive |
| Chlorine demand test | Positive |
| Taste and odor | Positive |

(2) Water is considered safe for treatment by the usual methods, if all the tests give the results indicated below:

| | |
|----------------------|--------------|
| Arsenic test | Negative |
| pH test | pH below 6.0 |
| Mustard test | Negative |
| Chlorine demand test | Negative |
| Taste and odor | Negative |

62. Replenishing Reagents for Field Water-quality-control Set

Reagents used to replenish the field water-quality-control set are prepared with boiled distilled water. Quantitative reagents are standardized before use.

| <i>Item</i> | <i>Description</i> |
|------------------------------|---|
| Ammonia alum capsules. | Place 0.99 grams (g), plus or minus 0.05 g, of chemically pure $(\text{NH}_4)_2\text{SO}_4\text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$ in each capsule. If capsules are not available, substitute glass vials. |
| Barium chloride solution. | Dissolve barium chloride in 2.0 normal hydrochloric acid. Precipitate two 50-ml samples of this solution as barium sulfate, filter, ignite, and weigh to determine the effective concentration. Adjust the solution strength so 1 ml of solution will be equivalent to 10 milligrams (mg) of sulfate radical. |
| Methyl orange solution. | Dissolve 1.0 g of methyl orange in 1 liter of water. |
| Phenolphthalein solution. | Dissolve 1.0 g of phenolphthalein in 100 ml of 50 percent ethyl alcohol solution and neutralize with 0.02 normal sodium hydroxide. |
| Potassium chromate solution. | Dissolve 250 g of potassium chromate in 1 liter of water. |
| Silver nitrate solution. | Dissolve silver nitrate in water. The concentration shall be such that 1 ml of the solution is equivalent to 5 mg of chloride radical. |

| Item | Description |
|----------------------------|--|
| Soap solution | <p>Prepare this solution and standardize it against CaCl_2 as follows:</p> <p><i>Standard calcium chloride solution.</i> Dissolve 0.500 g of pure calcite (calcium carbonate) with a little dilute hydrochloric acid, being careful to avoid spattering. Wash down with carbon-dioxide-free distilled water and neutralize it with ammonium hydroxide to slight alkalinity, using litmus as an indicator. Make up to 500 ml with carbon-dioxide-free distilled water and store in a glass stoppered bottle. One ml of this solution is equivalent to 1 mg of calcium carbonate.</p> <p><i>Standard soap solution.</i> Make up stock solution by shaking vigorously approximately 100 g of pure powdered castile soap in 1 liter of 80 percent grain alcohol. Let this solution stand at least overnight, then decant. The stock soap solution is approximately four times as strong as the dilute soap solution. Take a portion of the stock solution, dilute with 30 percent grain alcohol until, when titrated against CaCl_2 solution, 1 ml of the resulting dilution is equivalent to 2.5 ml of the standard calcium chloride solution, after allowance has been made for lather factor.</p> |
| Sodium carbonate capsules. | <p>Place 0.99 g, plus or minus 0.05 g, of anhydrous sodium carbonate in each capsule. If capsules are not available, substitute glass vials. These containers must be distinctively marked to differentiate them from those used for alum.</p> |
| Sulfuric acid solution. | <p>This solution shall be 0.100 normal.</p> |
| Turbidity solution. | <p>Add about 5 g of Fuller's earth to 1 liter of distilled water, thoroughly agitate intermittently for 1 hour and then allow to stand 24 hours. Withdraw super-</p> |

*Item**Description*

natant without disturbing the sediment in the bottom and test the turbidity with the Jackson candle turbidimeter. Dilute to 120-ppm turbidity.

To prevent bacterial growth in the solution, add 50 mg, plus or minus 10 mg, of mercuric chloride, and 0.5 g, plus or minus 0.1 g, of mercury to the bottle of solution.

Zeolite, synthetic

The synthetic zeolite should be replaced by materials similar and equal to Zee-Karb-Na, a synthetic zeolite manufactured by the Permutit Company, 330 West 42d Street, New York, New York. Wash the zeolite free of fines with distilled water. Approximately 50 g of material are needed. If new zeolite is not available, the old material may be regenerated by shaking it for 5 minutes in a 15 percent solution of sodium chloride and then rinsing it thoroughly with distilled water.

CHAPTER 4

ENGINEER WATER SUPPLY EQUIPMENT

Section I. WATER PURIFICATION UNIT, TRUCK-MOUNTED (MOBILE)

63. General

a. DESCRIPTION. The mobile water purification unit consists primarily of a chlorinator, a gasoline motor coupled to a self-priming centrifugal pump, venturi tubes, two chemical pots, a pressure-type rapid sand filter, a test kit for determining chlorine residual and pH, hose, tools, and spare parts. Figure 30 shows the mobile unit in operation. The entire unit, either the open-body or closed-body type, is mounted on a 2½-ton, 6x6, truck chassis. Body type does not affect the operating of the unit. See TM 5-2030 for a detailed comparison of the two types.

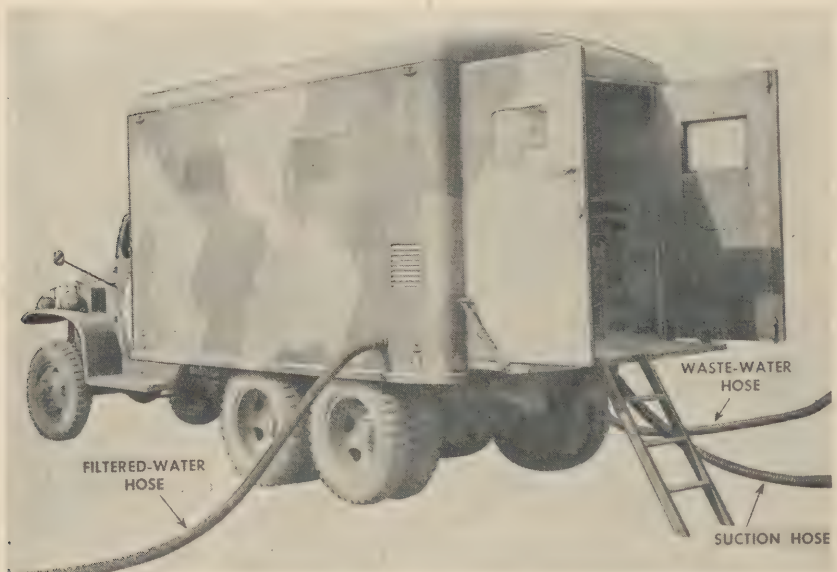


Figure 30. Water purification unit, truck-mounted (mobile).

b. **PHYSICAL CHARACTERISTICS.** Physical characteristics of the water purification unit are given below:

| | |
|-----------------------------------|------------------|
| Total weight, truck and unit..... | 8.3 tons |
| Over-all length | 22 feet |
| Width | 8 feet |
| Height | 10 feet 6 inches |

c. **OPERATING CHARACTERISTICS.** A three-man detail is required for continuous operation, including one man to operate the unit, one man for other tasks such as distribution, operation of booster pumps, and other functions, and one man as a relief operator. For planning purposes, the average amount of water treating chemicals used per 1,000 gallons of water is $\frac{3}{4}$ pound of alum, $\frac{1}{4}$ pound of soda ash, and $\frac{1}{2}$ ounce of chlorine. It must be remembered that more or less chemicals may be required, depending on the water source used.

64. Use

a. **PURPOSE.** The purpose of the mobile water purification unit is to furnish clear, potable water to troops in the field. The unit is designed to satisfy sanitary requirements and yet have a high capacity and mobility. It may accompany combat troops, but is more often used in the communications zone.

b. **CAPABILITIES.** Depending on the amount of impurities in the raw water, the unit can purify approximately 11,200 to 66,000 gallons of water in a 20-hour day. One truck-mounted unit on a source yielding 100 gpm of low-turbidity water can supply drinking water for a division. For efficient operation, the unit must be used with water supply equipment set No. 5. (See ASF Supply Catalog ENG 2.)

c. **LIMITATIONS.** Because of its weight, the unit cannot be operated on soft or boggy ground. It will not pump water from sources more than about 20 feet below the level of the pump. The treatment process will not remove all odors and tastes from water. Amoebic cysts (cause of amoebic dysentery) and cercariae of the schistosome (cause of schistosomiasis) are not entirely removed by the unit. If the presence of these cysts or cercariae is suspected, further treatment is necessary. (See pars. 37c(5) and 48.)

65. Functioning

a. **FLOW.** (1) *During production of filtered water.* The centrifugal pump draws raw water through the strainer and 2½-inch suction hose, past the chlorine diffuser, and into the pump body. (See fig. 31.) The pump impeller mixes the chlorinated raw water and forces it through the venturi tube; the tube measures the flow

in gpm and bypasses water to and from the chemical pots. The chemicals form a floc in the water. The water and floc go through the filter control valve and into the top of the filter. The floc collects on top of and in the filter sand and aids in removing the dirt and impurities from the water as it moves down through the filter. Filtered, chlorinated water flows out the bottom of the filter to the filtered-water tank through either or both discharge valves.

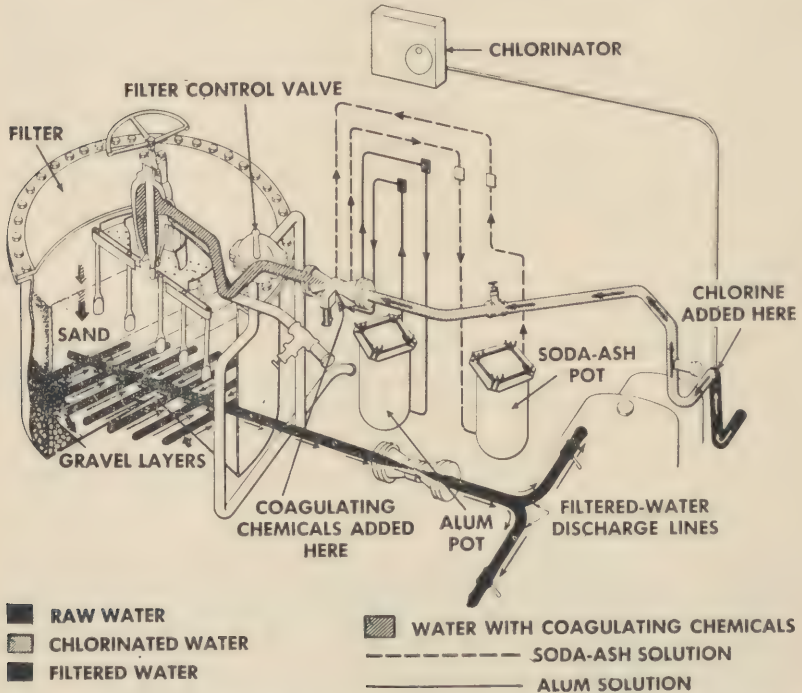


Figure 31. Flow diagram of water during production of filtered water in mobile unit.

(2) *During backwashing and filtering to waste.* During backwashing, the direction of flow is reversed by the filter control valve so the water enters at the bottom of the filter, moves upward through the filter material, returns to the filter control valve from the top of the filter, and passes out the waste line. (See fig. 32.) During filtering to waste (fig. 33), water is directed into the top of the filter, moves downward through the filter material, and returns from the bottom of the filter to the filter control valve which diverts it to the waste line.

b. **CHLORINATOR.** The chlorinator (fig. 34) feeds dry chlorine gas into the raw water at a maximum rate of 10 pounds of chlorine per 24 hours. It consists of a chlorine cylinder, compensa-

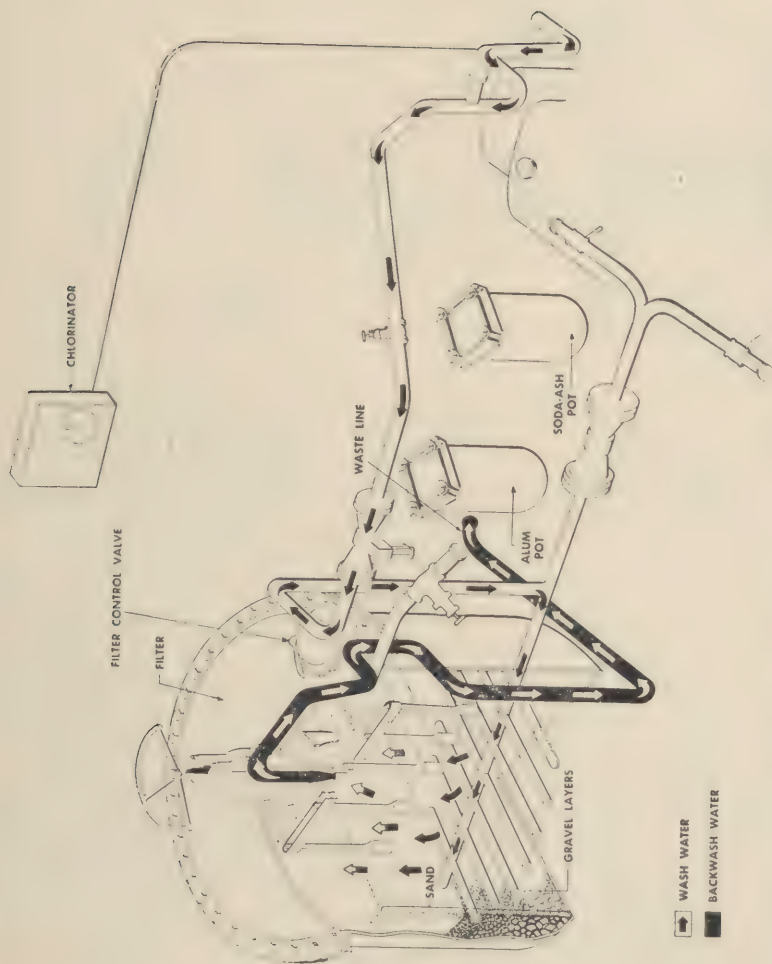


Figure 32. Flow diagram of water during backwashing of mobile-unit filter.

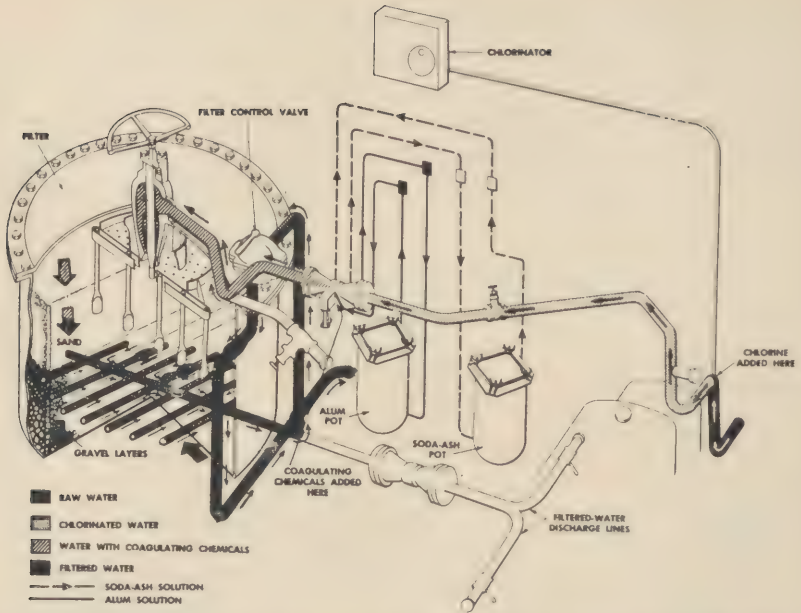


Figure 33. Flow diagram of water during filtering to waste in mobile unit.

tor, manometer, antiflood device, back-pressure valve, diffuser, and gauges for cylinder pressure and back pressure.

(1) The chlorine cylinder contains 16 pounds of liquid and gaseous chlorine under pressure. The gas goes through the main cylinder valve and auxiliary cylinder valve into the inlet tube.

(2) The compensator assembly (figs. 34 and 36(1)) maintains a constant flow of gas through the system regardless of changes in cylinder pressure. The smooth flow of chlorine is controlled by the diaphragm and inlet needle valve. The quantity of chlorine added is controlled with the chlorine control valve.

(3) The chlorine manometer measures the flow of chlorine gas in pounds per 24 hours. An improved manometer supersedes the older model and is found on all units of serial No. 376-A-373-43 or higher. Both models are shown in figure 34. The manometer is calibrated to read accurately when a constant chlorine pressure of 25 psi is maintained by the back-pressure valve.

(4) The antiflood device (fig. 34) warns the operator that water has come through the back-pressure valve. The device is a glass tube filled with silica-gel crystals which are yellow during normal operation but turn white when contacted by water.

(5) Chlorine is fed through the diffuser assembly (fig. 34, 36(3), and 39) into the raw water in the pump suction line.

c. PUMP. The pump draws raw water from the stream and

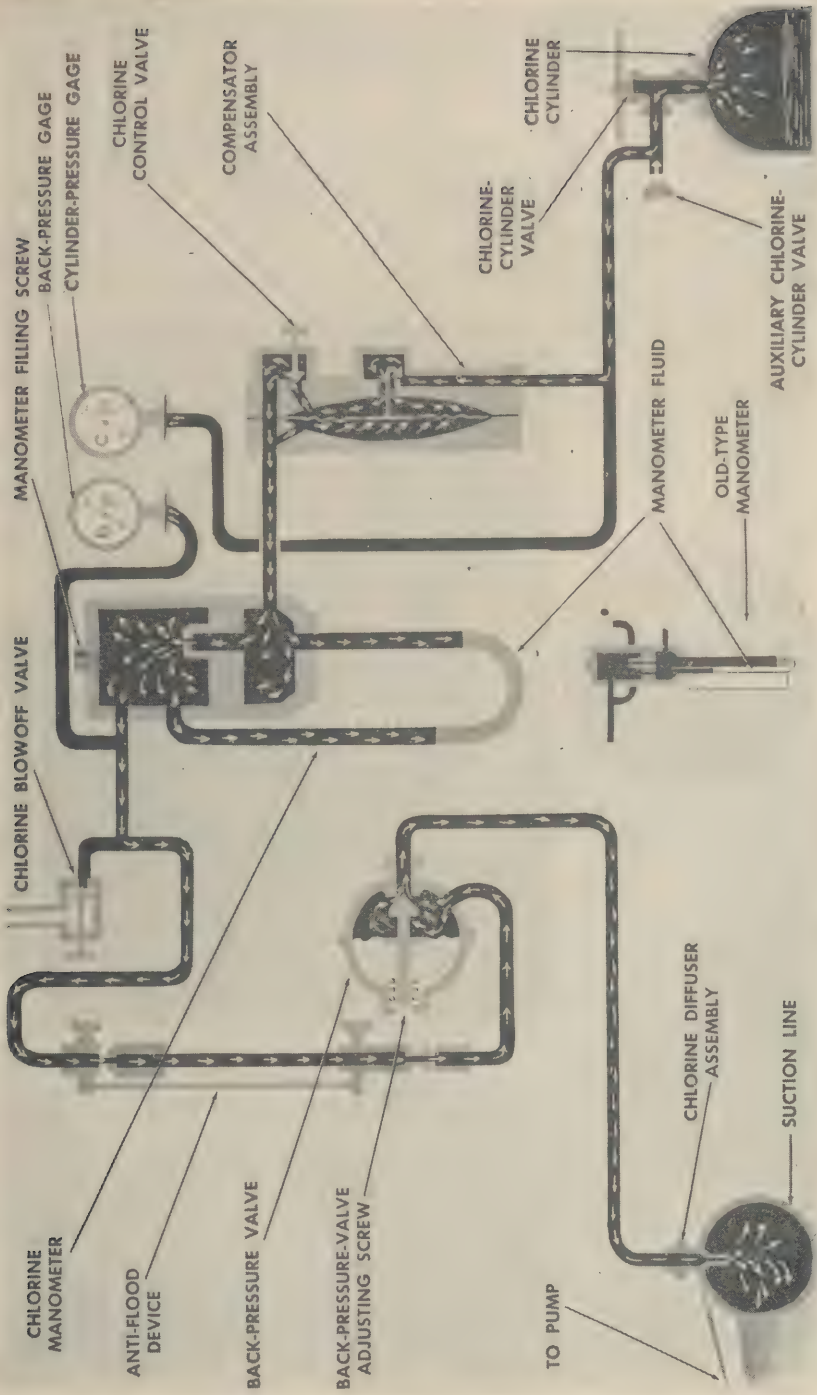


Figure 34. Flow diagram of chlorine gas through chlorinator of mobile unit.

pushes the water through the unit. (See figs. 31 and 36.) It is self-priming single-stage centrifugal-type with 2½-inch suction and a 2-inch discharge. It has a maximum capacity of 100 gpm at 2,000 rpm against a total head of 90 feet, of which 20 feet may be suction.

d. ENGINE. The engine drives the pump through a direct connection. It is a self-contained unit with gasoline tank, radiator, magneto, tachometer, oil-pressure gauge, and ignition switch.

e. FILTER. The pressure-type sand filter (fig. 36(1)) removes turbidity and bacteria from the water. It is 42 inches in diameter,

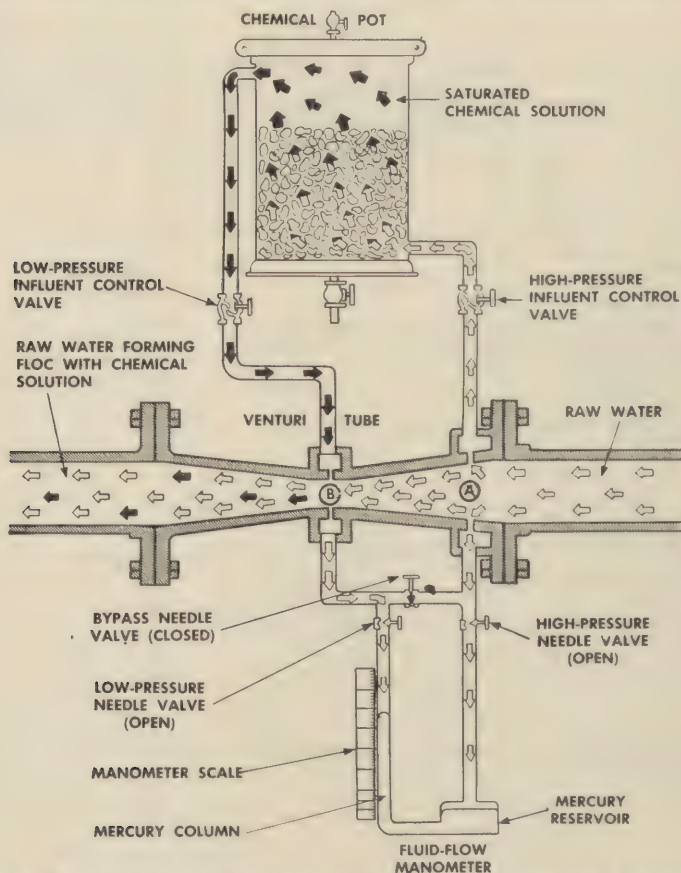


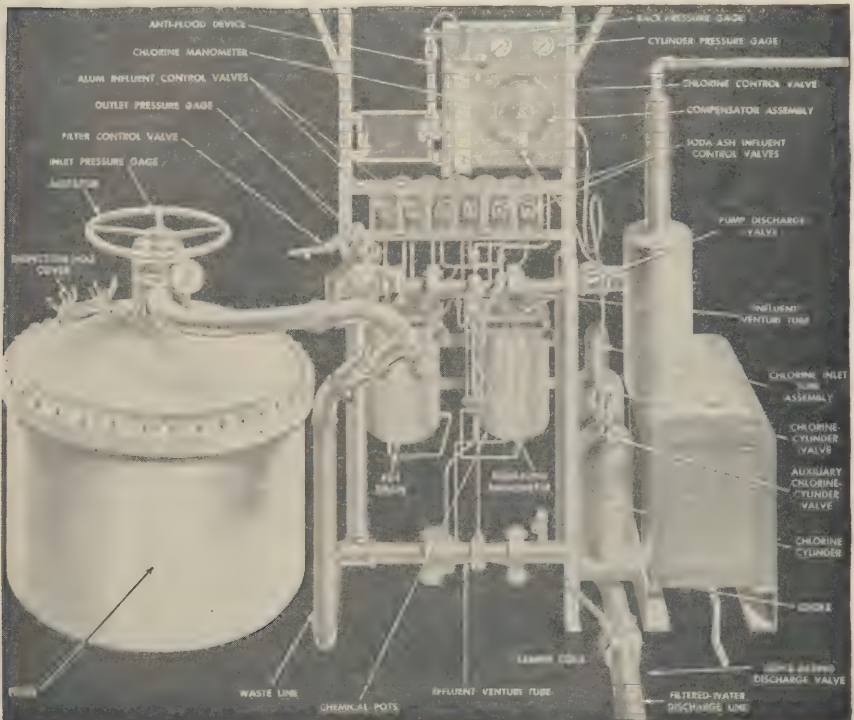
Figure 35. Flow diagram of water in fluid-flow manometer and chemical pots of mobile unit. Wherever there is a contraction in a water stream as at B above, the water pressure at the contraction is less than the pressure in the full-sized stream at A. Water flows through the chemical pot because of this difference in pressure between A and B. The manometer scale is calibrated in gpm, the mercury-column height varying with changes in water-pressure difference. It is possible to calibrate the scale in gpm because the pressure difference caused by the venturi tube increases and decreases proportionately with the flow of water in the tube.

fitted top and bottom with 2-inch pipe. There is an inspection hole and an agitator in the top. The agitator is rotated by hand to stir up the sand in the filter during backwashing. The filter is filled with three layers of gravel and a layer of sand as shown in figure 31.

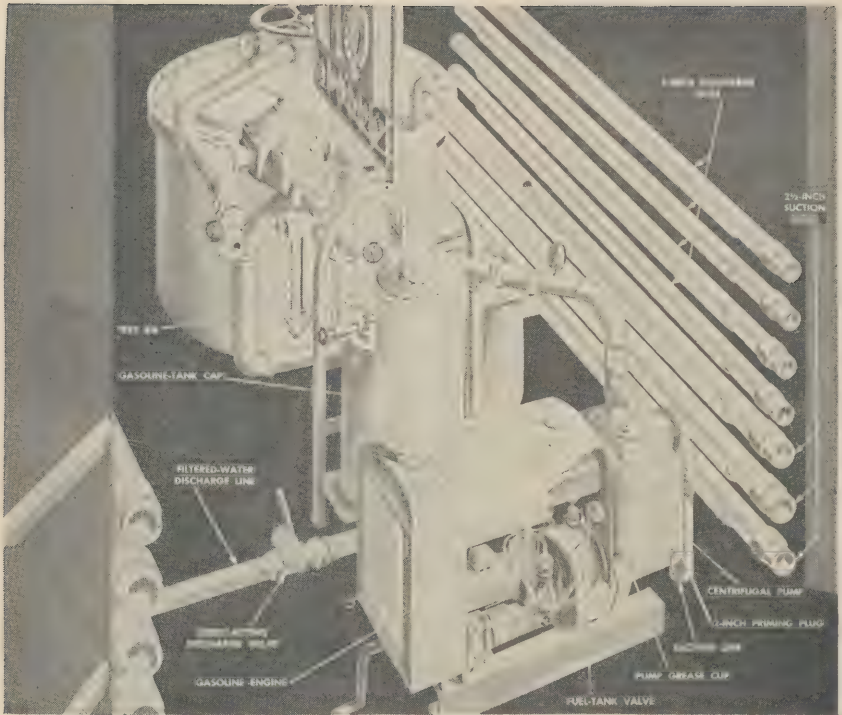
f. VENTURI TUBE AND FLUID-FLOW MANOMETER. The venturi tube (fig. 35) in the inlet water line measures the flow of water on the fluid-flow manometer (fig. 38) and causes a difference in water pressure which forces water to and from the chemical pots. There is also a venturi tube in the filtered-water discharge line. It is used when adding soda ash after filtration, and normally should be disconnected from the soda-ash pot, since it makes a cross connection between the raw and filtered water.

g. CHEMICAL POTS. The two chemical pots (fig. 36(3)) are tanks with inlet and outlet connections, watertight lids, and drains. For normal operation, the pot nearest the filter contains alum and the other pot contains soda ash. If no soda ash is needed and considerable alum is required, both chemical pots can be filled with alum.

h. FILTER CONTROL VALVE. The filter control valve (fig. 36(1))



① Operator's view of mobile-unit interior.
Figure 36.



② *End view of mobile-unit interior.*
Figure 36 (Contd.).

controls the direction of flow of water to the filter. It has three settings, washing (*W*), filtering to waste (*FW*), and filtering (*F*).

i. HOSE. Ten-foot lengths of 2½-inch rubber suction hose and 2-inch rubber discharge hose are carried in racks inside the body. The open-body unit is provided with six lengths of discharge hose and four lengths of suction hose. The closed-body unit has eight lengths of discharge hose and six lengths of suction hose.

j. TEST EQUIPMENT. The standard comparator (par. 57) is used in making pH and residual-chlorine determinations.

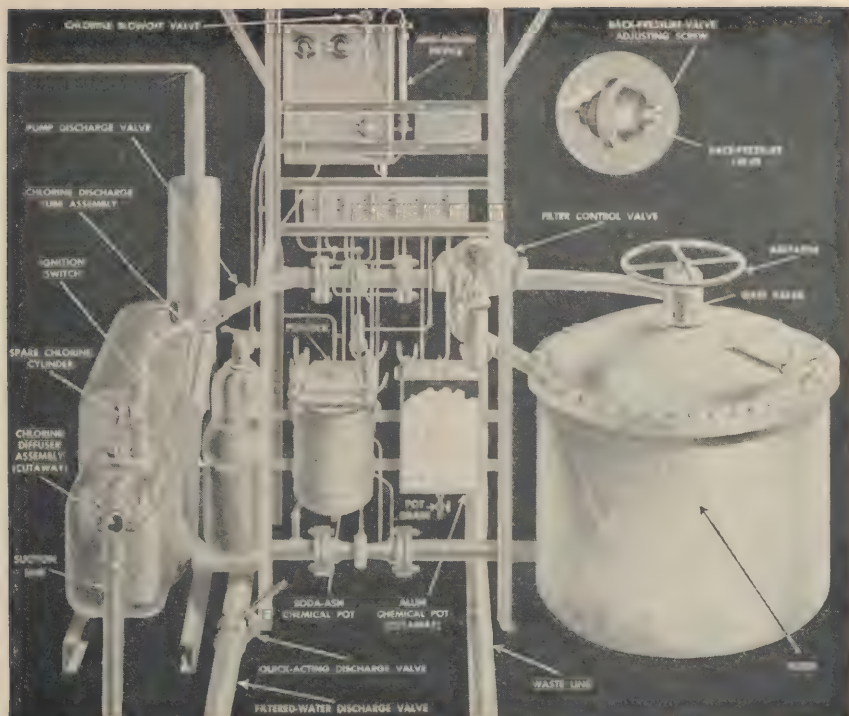
66. Precautions

Before operating unit, consult TM 5-2030 for detailed instructions. Specific precautions are noted below:

a. Park truck on dry, level spot near source; do not park too close to streams subject to flash floods.

b. Put intake strainer in a bucket or tie it to a stake to keep it off stream bottom. (See fig. 37.) (For other intakes, see paragraph 150.)

c. Add additional mercury to fluid-flow manometer as required. (See fig. 38.)



③ View of rear of chemical and chlorinator control panels.
Figure 36 (Contd.).

d. After opening each valve, check for chlorine leaks with an open ammonia bottle. Never operate chlorinator if chlorine is leaking. (See figs. 39 and 40.)

e. Clean chlorine lines with chloroform, carbon tetrachloride, or wood alcohol. *Do not use water.*

f. When starting a filter cycle, always filter to waste until filter effluent is clear.

g. Do not filter water faster than necessary to meet requirements, and never exceed 60 gpm.

h. When unit is shipped or major repairs are made to the chlorinator, open chlorine blowoff valve (fig. 36(3)) and close it tightly when there is no pressure in the system.

67. Field Maintenance of Unit

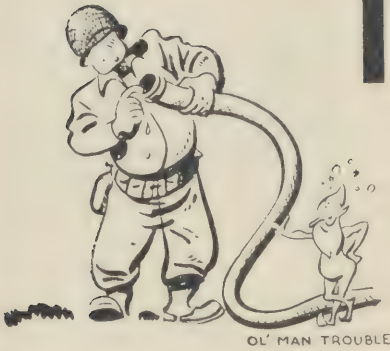
For field maintenance of unit, see TM 5-2030.

68. Hypochlorinator Mounting Bracket

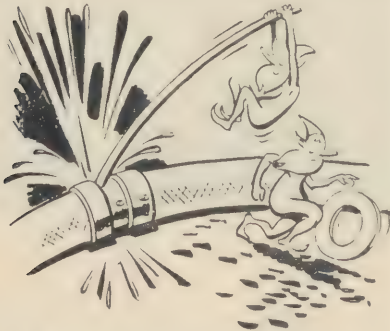
On the later mobile units manufactured, a bracket is placed between the engine radiator and the chlorine-cylinder stand to hold

WATER WON'T MOVE

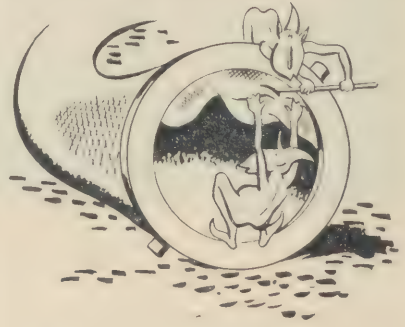
IF



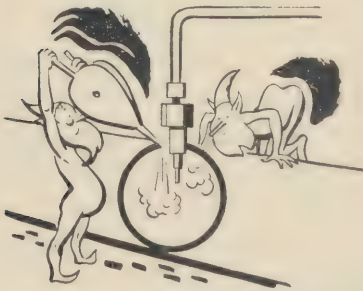
1

THERE IS GRASS OR
MUD AROUND STRAINER

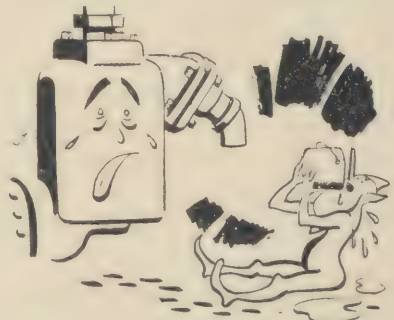
2

HOSE JOINTS ARE LOOSE
AND WITHOUT GASKETS

3

HOSE LINER HAS
COLLAPSED

4

AIR IS LEAKING THROUGH
CHLORINE DIFFUSER

5

PUMP ISN'T PRIMED

Figure 37. Possible difficulties to check if pump does not deliver water.

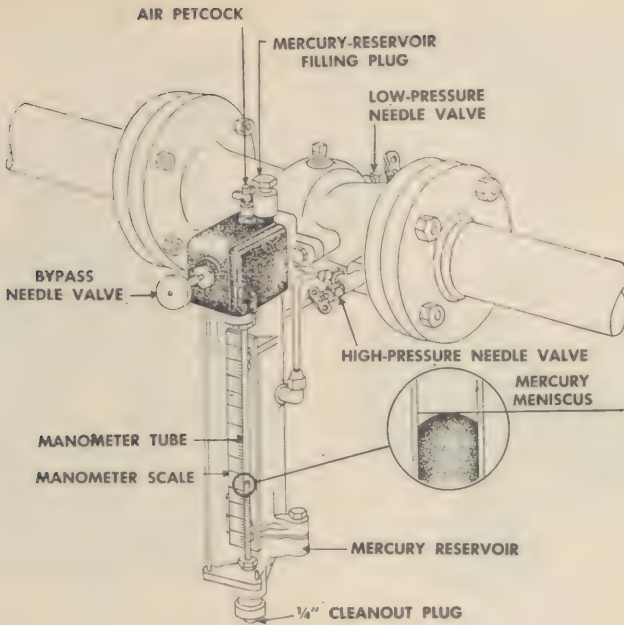


Figure 38. Fluid-flow manometer.

a hypochlorinator assembly similar to the hypochlorinator issued with the pumping and treatment assembly of the portable unit. The hypochlorinator discharge hose is attached to the nipple outlet on the pump discharge line.

Section II. WATER PURIFICATION UNIT, PORTABLE

69. General

a. DESCRIPTION. The portable water purification unit consists of a pumping and treatment assembly, a filter assembly, hose, tools, and a color comparator for determining pH value and chlorine residual. This unit is the basic component of water supply equipment sets Nos. 1 and 4. (See ASF Supply Catalog ENG

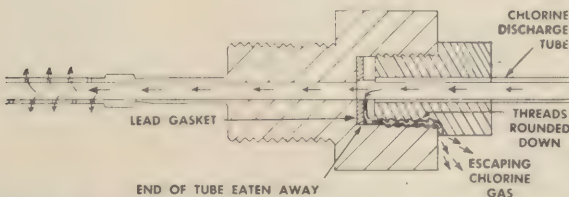
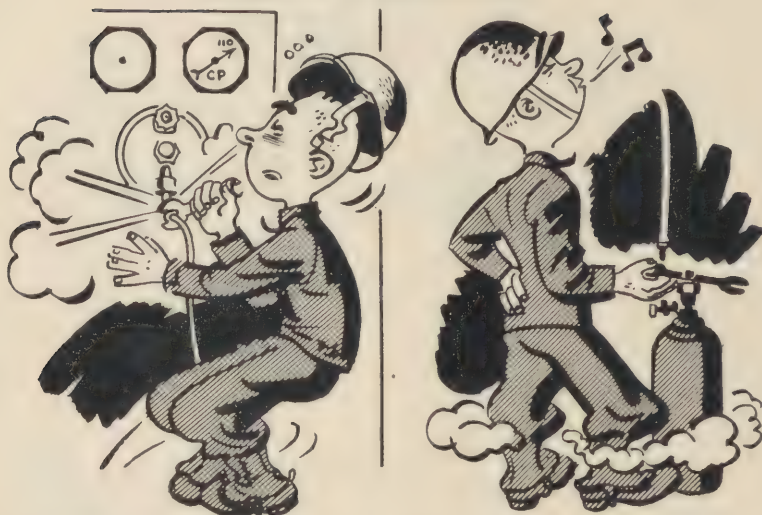


Figure 39. Chlorine leakage damaging diffuser assembly.

CHLORINE PRECAUTIONS



- ① DON'T OPEN UNIONS IN CHLORINE LINES WITH PRESSURE ON LINE** **② IN CASE OF A LEAK SHUT OFF CYLINDER VALVE, KEEP HEAD HIGH, KEEP CALM**

Figure 40. Chlorine precautions.

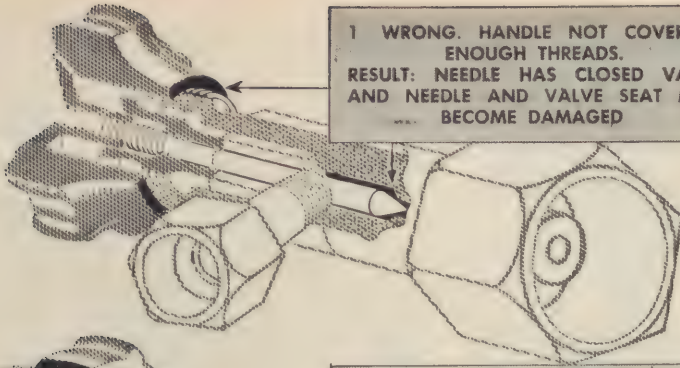
2.) The pumping and treatment section consists of a gasoline engine coupled to a 55-gpm centrifugal pump, two chemical feed tanks, a hypochlorinator, and two tool boxes. Figure 42 shows the portable unit in operation.

b. PHYSICAL CHARACTERISTICS. Weight and dimensions of the portable purification unit are given below.

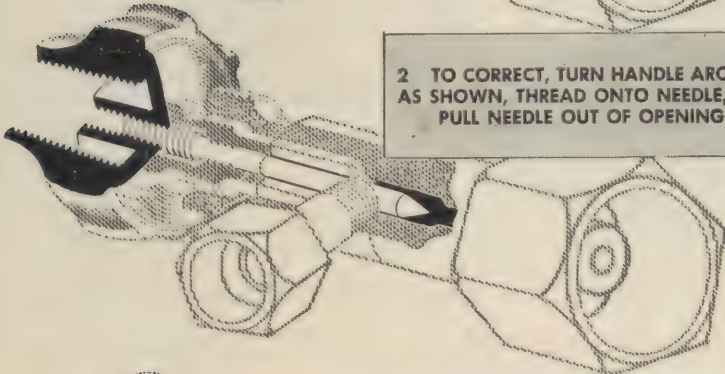
| | Weight (pound) | Over-all diameter (inches) | Height (inches) | Width (inches) | Length (inches) |
|--------------------|-------------------|----------------------------------|--------------------|-------------------|--------------------|
| Filter assembly | 450 | 24 | 46 | | |
| Treatment assembly | 290 | | 38 | 25 | 31 |

c. OPERATING CHARACTERISTICS. A three-man detail is required for continuous operation, including one man to operate the unit, one man for other tasks such as distribution, operation of booster pumps, and other functions, and one man as a relief operator. For planning purposes the average amount of water treating chemicals used per 1,000 gallons of water is $\frac{3}{4}$ pound of alum, $\frac{1}{4}$ pound of soda ash and $\frac{1}{2}$ ounce of chlorine. It must be remembered that more or less chemicals may be required, depending on the water sources used.

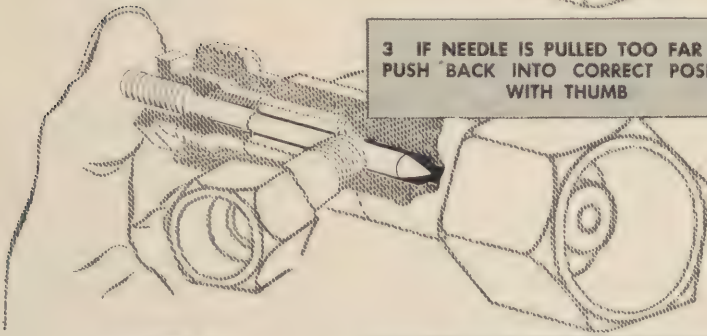
1 WRONG. HANDLE NOT COVERING ENOUGH THREADS. RESULT: NEEDLE HAS CLOSED VALVE AND NEEDLE AND VALVE SEAT MAY BECOME DAMAGED



2 TO CORRECT, TURN HANDLE AROUND AS SHOWN, THREAD ONTO NEEDLE, AND PULL NEEDLE OUT OF OPENING.



3 IF NEEDLE IS PULLED TOO FAR OUT, PUSH BACK INTO CORRECT POSITION WITH THUMB



4 RIGHT. HANDLE AND NEEDLE IN CORRECT POSITION. VALVE IS CLOSED BY NEEDLE AND ALL BUT ONE THREAD IS COVERED BY HANDLE

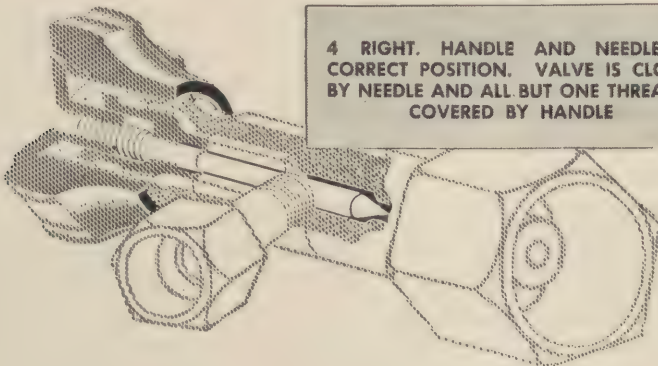


Figure 41. Four steps in adjusting chlorine valves.

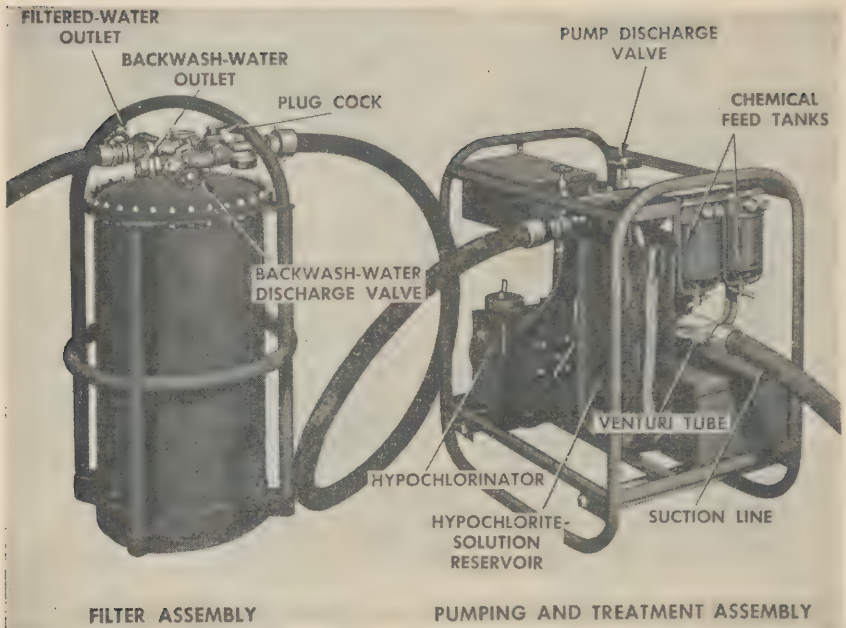


Figure 42. Filter and pump and engine assemblies of portable water purification unit.

70. Use

a. PURPOSE. The purpose of the portable purification unit is to provide potable water for troops in the field. This unit is the principal purification equipment used by combat troops.

b. CAPABILITIES. This unit can chlorinate and filter about 4,000 to 11,000 gallons of water in a 20-hour day, depending on the amount of impurities in the raw water. This capacity can be doubled for well sources which require chlorination only. Total output can also be increased by operating two sand filters in parallel, supplying both from a single pumping and treatment section. On the other hand, the water quality can be improved by maintaining a 10-gpm rate and taking advantage of the increased filter area. Special care must be taken to keep flow rates uniform through both filters.

c. LIMITATIONS. The portable water purification unit without pretreatment (par. 36) cannot clarify water of high turbidity nor can it remove amoebic cysts (cause of amoebic dysentery) and cercariae of the schistosome (cause of schistosomiasis). If these cysts or cercariae are present, special treatment (pars. 37*c*(5) and 48) is necessary. The maximum suction lift of the pump is about 20 feet.

71. Functioning

a. FLOW. (1) *During production of treated water.* Raw water is drawn through the brass strainer and 1½-inch suction hose, past the venturi tube, and into the pump. (See fig. 43.) At the venturi tube, solutions of soda ash and alum are added to form the floc. The water is then drawn through the pump and discharged past the hypochlorite-solution inlet to the filter. The floc is deposited in the filter sand and aids in removing impurities from the water moving through the filter. Filtered, chlorinated water flows out the bottom of the filter into the filtered-water tank.

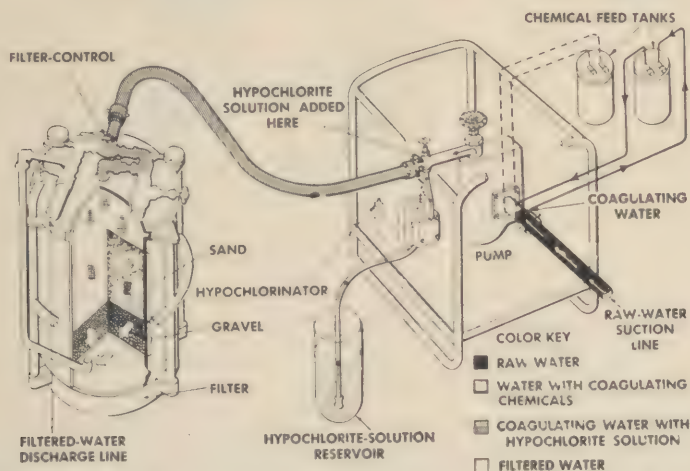


Figure 43. Flow diagram of water during production of filtered water in portable unit.

(2) *During backwashing and filtering to waste.* During backwashing, the direction of flow through the filter is reversed. (See fig. 44.) Water enters the *bottom* of the filter and flows out the backwashwater valve at the *top* of the filter. When filtering to waste, the flow is the same as during production of treated water except that the discharged water is wasted. The alum and soda-ash feeds are shut off during backwashing operations.

b. CHEMICAL FEED TANKS. The two chemical feed tanks (fig. 42) hold solid chemicals which dissolve and form alum and soda-ash solutions as water flows through the tank. Raw water enters each chemical tank through the high-pressure control valve on top of the tank, and the chemical solution leaves the tank through the low-pressure control valve. The difference in pressure between the high and low valves is caused by the venturi tube. (See fig. 35.)

c. PUMP. The self-priming single-stage centrifugal pump draws

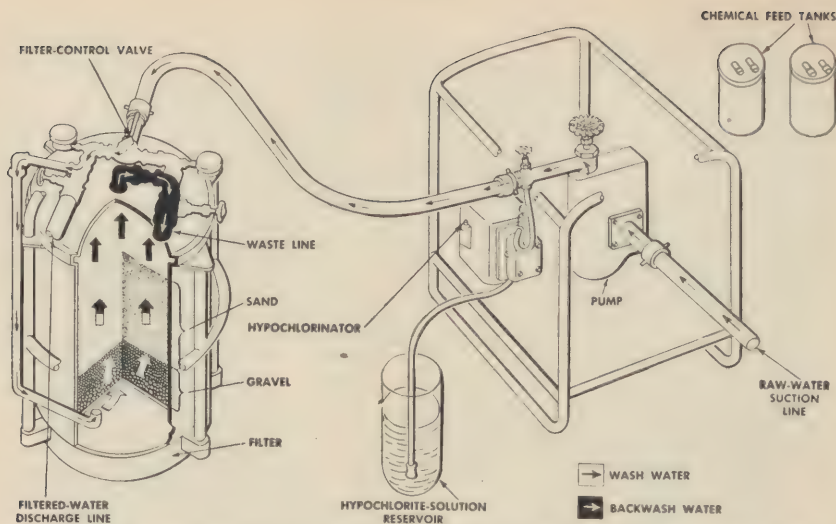


Figure 44. Flow diagram of water during backwashing of portable unit.

raw water from the source and forces it through the unit. It pumps 55 gpm against a 50-foot total head.

d. **ENGINE.** The one-cylinder gasoline engine drives the centrifugal pump through a direct connection.

e. **HYPOCHLORINATOR.** The hypochlorinator is a belt-driven diaphragm pump with a variable stroke which pumps hypochlorite solution into the water. On the suction stroke, hypochlorite solution is pulled into the pump head (fig. 45) through the intake poppet valve, and on the discharge stroke, it is forced into the discharge line of the water pump through the outlet poppet valve. The quantity of hypochlorite solution pumped is controlled by the stroke-control handle. (See fig. 46(1).)

f. **SAND FILTER.** The sand filter clarifies the water as it passes through the filter. It consists of a tank with inlet and outlet piping, and valves to control direction and quantity of flow. The filter is filled with a 4-inch layer of gravel overlain with an 18-inch layer of sand. (See fig. 43.) At 10 gpm, the filter is operating at 4 times the usual rate for rapid sand filters. Thus for best results, never operate the filter faster than necessary to meet troop requirements.

72. Precautions

Before operating unit, consult TM 5-2000 for detailed instructions. Specific precautions are noted below.

a. Place pumping and treatment section and filter section in a dry, level place near water source. If the filter section tips, filter efficiency is seriously reduced.

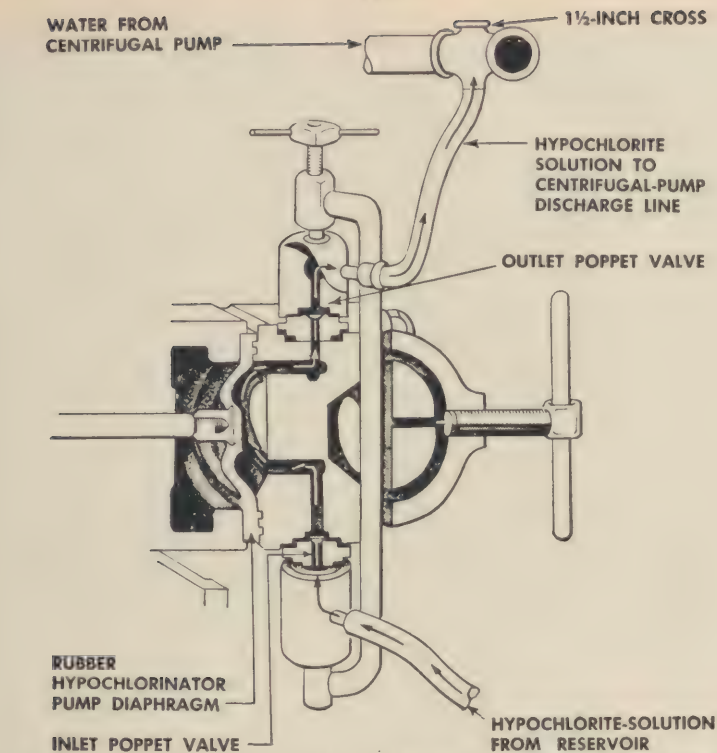
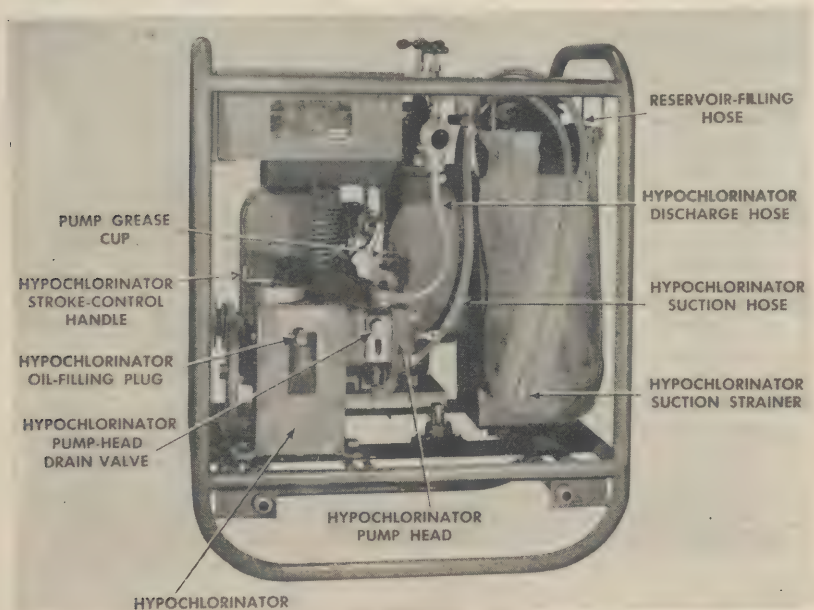
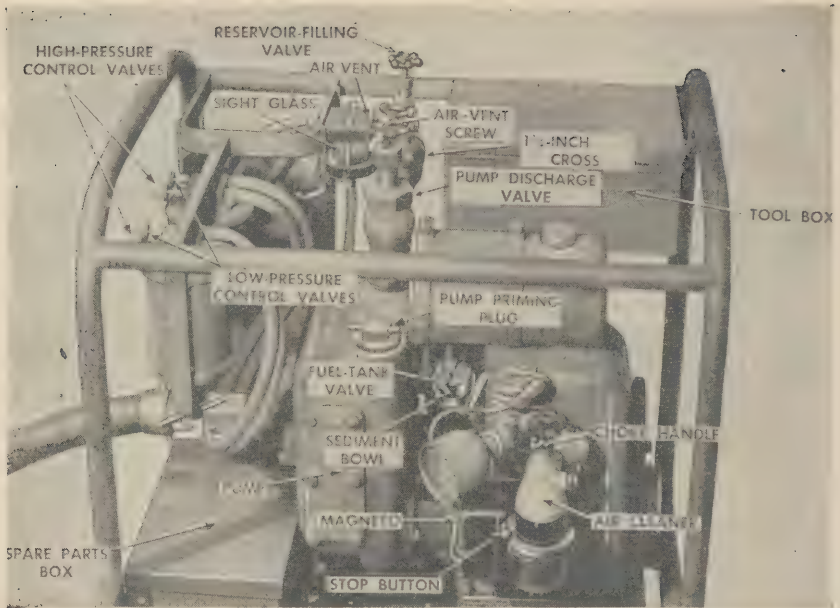


Figure 45. Flow diagram of hypochlorite solution in hypochlorinator.



① Pumping and treatment assembly showing hypochlorinator details.
Figure 46.



(2) Pumping and treatment assembly showing engine details.
Figure 46 (Contd.).

b. Always use a small strainer on end of hypochlorinator suction hose.

c. Do not use unnecessary lengths of hose.

d. Do not use powdered alum or granulated soda ash in the chemical feed tanks.

e. Never fill filter from top because incoming water will dig channels in the sand and reduce filter efficiency.

f. At beginning of each cycle, filter to waste until filter effluent is clear.

g. Do not filter water faster than necessary to meet requirements, and never exceed 10 gpm.

h. If filtered water is turbid after 10 minutes of filtration and pH is at optimum, reduce flow.

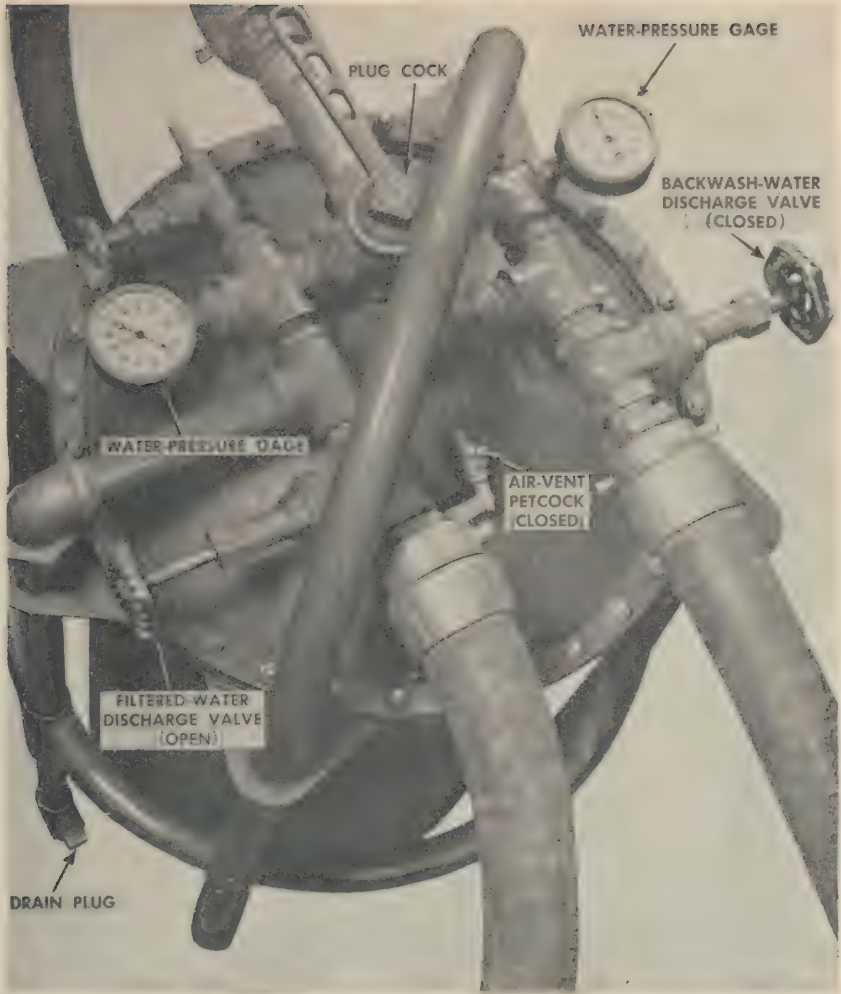
i. If filtered water remains turbid after 10 more minutes of filtration, stop engine and clean inside of all four chemical feed hoses.

j. If filtered water still does not clear up, use pretreatment.

k. Backwash filter when—

(1) Gauges show 10 to 15 pounds pressure difference across filter. (See fig. 47.)

(2) Filtered water becomes cloudy.

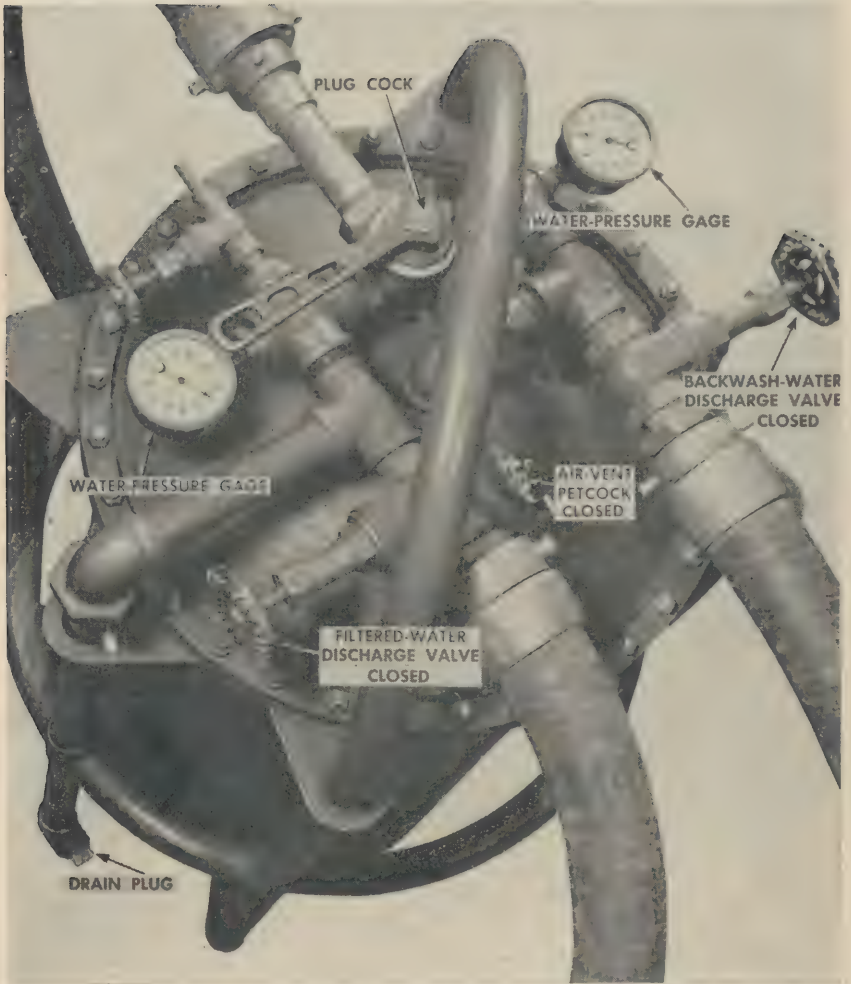


① *Valves set for filling filter assembly.*
Figure 47.

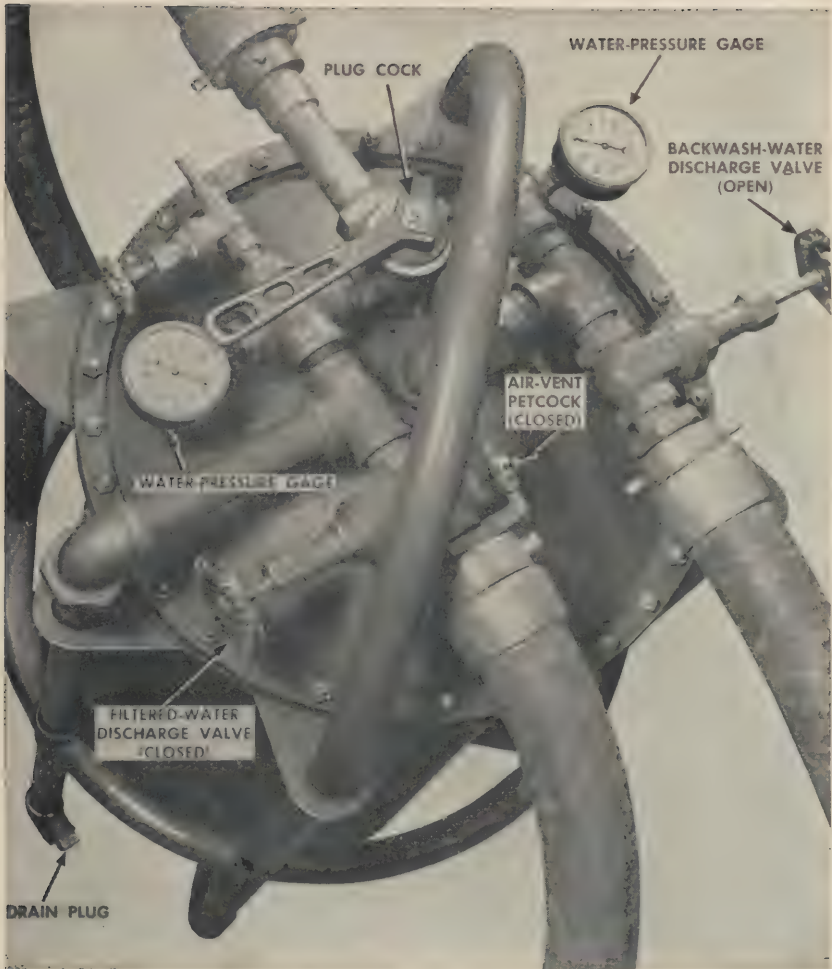
- (3) Capacity falls off appreciably.
- (4) Unit is shut down for several hours.

73. Mounting Portable Unit in Trailer

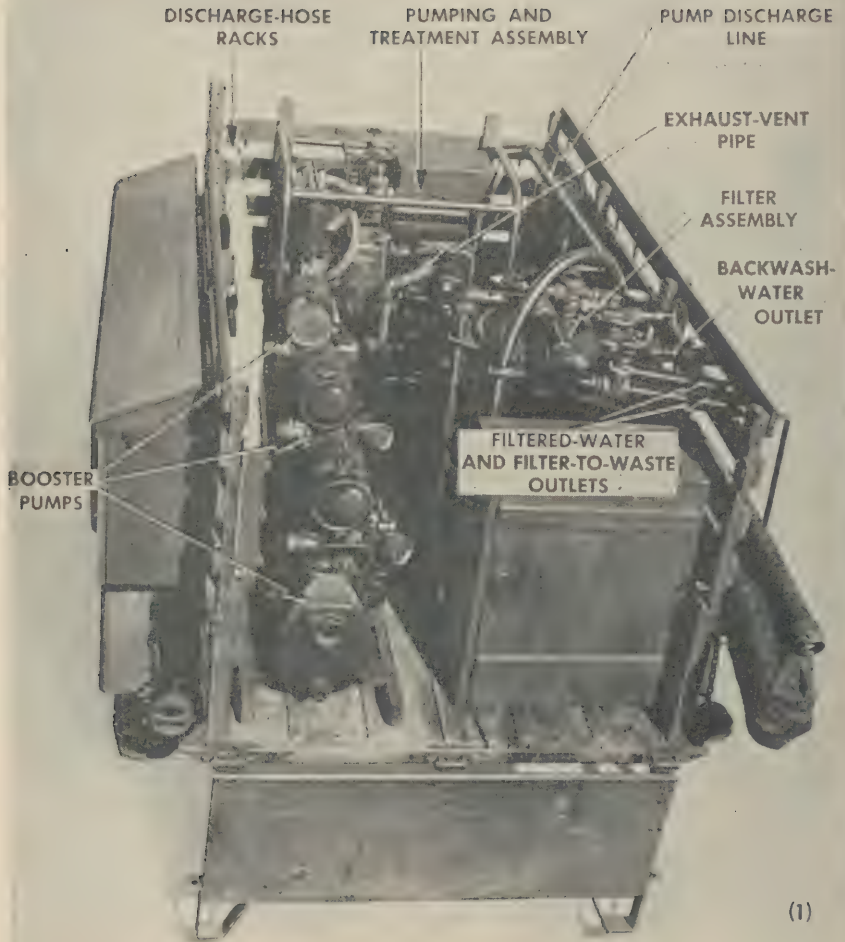
The entire portable unit can be mounted in a trailer together with booster pumps and tanks. (See fig. 48(1) and (2)).



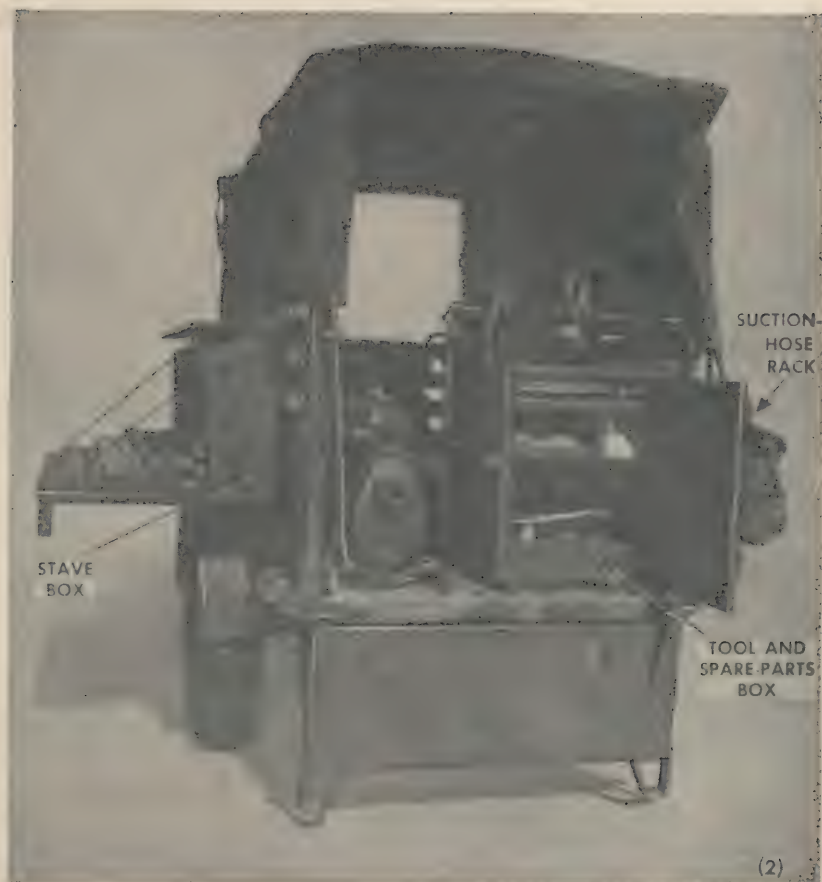
② Valves set for backwashing filter assembly.
Figure 47 (Contd.).



③ Valves set for filtering.
Figure 47 (Contd.).



① Top view of portable unit mounted on a 1-ton trailer.
Figure 48.



② End view of trailer.
Figure 48 (Contd.).

Section III. WATER PURIFICATION EQUIPMENT, DIATOMITE, PACK (MAN), 15-GPM

74. General

a. DESCRIPTION. The water purification equipment, diatomite, pack (man), 15-gpm, consists basically of a pressure filter, a diatomaceous-slurry-feeding apparatus, two gasoline-engine-drive pumping assemblies, and auxiliary equipment including four fabric tanks, testing apparatus, hand pump, and accessories. (See ASF Supply Catalog ENG 2.) Figure 49 shows the filter assembly and pump and engine in operating position.

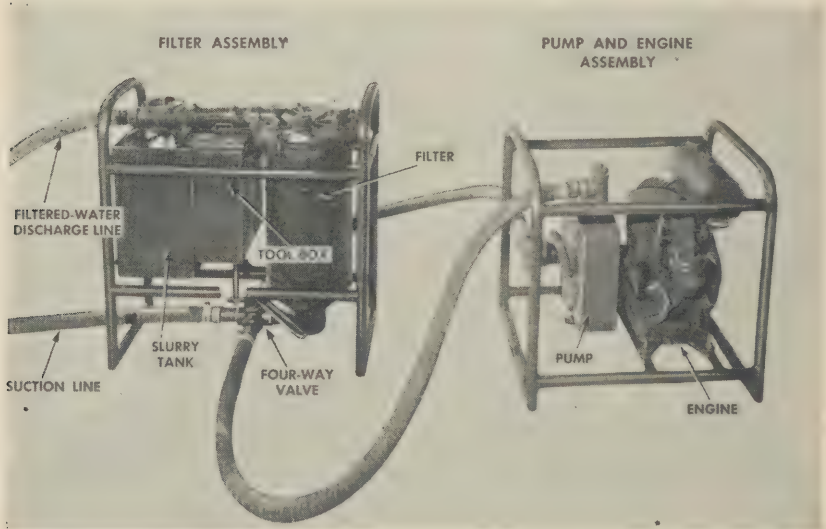


Figure 49. Filter, and pump and engine assemblies of pack diatomite water purification unit.

b. PHYSICAL CHARACTERISTICS. Physical characteristics of the equipment are given below:

| | Length (inches) | Width (inches) | Height (inches) | Approximate weight (pound) |
|---------------------------|--------------------|-------------------|--------------------|----------------------------------|
| Filter assembly | 25 $\frac{3}{4}$ | 10 $\frac{3}{4}$ | 25 $\frac{1}{4}$ | 62 |
| Pump and engine assembly* | 21 | 21 | 21 | 65 |

* Figures are correct for pump and engine development model. They indicate approximate values only for pump and engine to be issued with pack equipment.

c. OPERATING CHARACTERISTICS. A three-man detail is required for continuous operation, including one operator, one man to batch

and pretreat water, and a relief operator. For planning purposes, the average amount of water treating chemicals used per 1,000 gallons of water is $3\frac{1}{4}$ pound of alum, $\frac{1}{4}$ pound of soda ash, $\frac{1}{2}$ ounce of chlorine, and 1 pound of diatomaceous-silica filteraid. It must be remembered that more or less chemicals may be required, depending on the water source used.

75. Use

a. PURPOSE. The purpose of 15-gpm pack water purification equipment is to provide potable water for troops in the field. It is designed to be moved to the water point by pack animal or by individual man packs.

b. CAPABILITIES. The filter removes all amoebic cysts and cercariae of the schistosome. It weighs approximately one-tenth as much as a sand filter of the same capacity. Diatomite filtration of pretreated water produces filtered water of less than 0.1-ppm turbidity and removes over 90 percent of all bacteria.

c. LIMITATIONS. Diatomaceous silica must be carried with this unit in addition to the standard water purification chemicals, soda ash, alum, and hypochlorite. There are no mechanical chlorine, alum, or soda-ash feeds with pack equipment. Chemicals are added by hand to the treatment tanks.

d. TRANSPORTATION. (1) The entire unit and its auxiliary equipment can be carried in nine man packs or on three pack animals. If transportation facilities are limited, only essential components of the set can be carried. Thus, if only two pack animals or six men are available, the following packs are sufficient:

Pack No. 1—Filter assembly.

Pack No. 2—Pump and engine assembly.

Pack No. 3—Hose and diatomaceous silica.

Pack No. 5—500-gallon tank and hose.

Pack No. 6—500-gallon tank and hose.

Pack No. 9—Spare parts and supplies.

(2) If only one pack animal or three men are available, a small amount of water may be obtained with packs 1, 2, and 3, by filling containers directly from the filter assembly. Whenever possible, the complete set should be used.

76. Functioning

a. FLOW. (1) *During production of filtered water.* The centrifugal pump draws unfiltered water through the strainer, $1\frac{1}{4}$ -inch suction hose and four-way valve, past the slurry-feed inlet, and into the pump body. (See fig. 50.) The pump impeller mixes the unfiltered water and filteraid slurry and discharges the mixture

through the four-way valve into the baffle chamber at the bottom of the filter shell. The velocity of the water is decreased by the baffle; the water rises uniformly in the shell and filters horizontally through the septum elements. In passing through the septum elements, the water deposits a layer of filteraid and impurities on the elements. (See fig. 53.) This layer of filteraid and impurities forms a filter cake which removes suspended matter from the water passing through it. The filtered water passes through the collecting head to the filtered-water tank. The clear water operates the water motor of the slurry-feeding apparatus. A small stream of clear water is drawn from the petcock in the discharge pipe (fig. 50) to replenish the slurry added to the raw water.

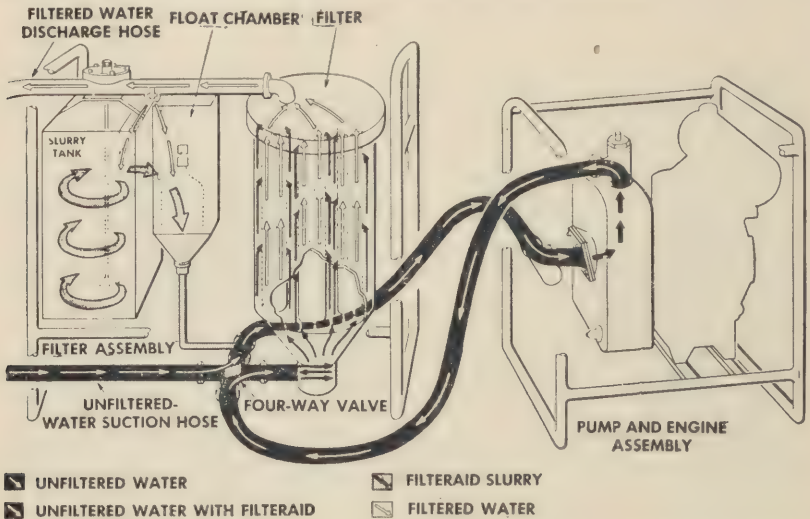


Figure 50. Flow diagram of water during production of filtered water in pack diatomite unit.

(2) *During backwashing.* The direction of flow is reversed by the four-way valve during backwashing so filtered water enters the top of the filter, flows out through the septums in reverse, dislodges the filter cake, and washes it out the bottom of the filter through the pump to waste. (See fig. 51.)

(3) *During precoating.* During precoating, which always precedes the production of filtered water, the initial layer of filteraid necessary to remove suspended matter from water is deposited on the filter elements. Direction of flow is the same as for the production of treated water. However, if filtered water is available, it is drawn into the filter through the suction hose. The water discharged from the top of the filter is wasted.

b. **FILTER.** The filter removes suspended matter from the

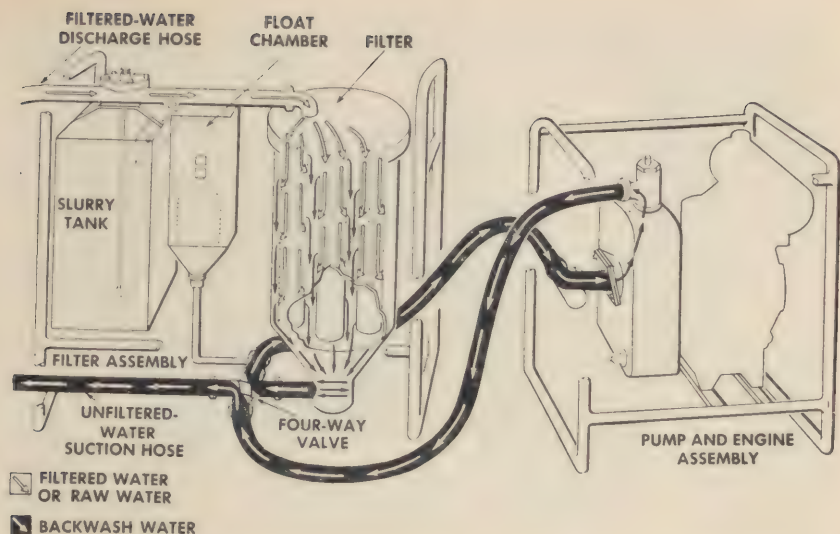


Figure 51. Flow diagram of water during backwashing of pack diatomite unit.

water. It consists of seven septum elements attached to an aluminum collector head and contained within a stainless-steel shell.

(1) The septum elements (fig. 53) support the filter cake and permit the passage of water. Each septum element is a permeable hollow tube held to the filter head by a tie rod, and sealed at each end by rubber gaskets.*

(2) The collector head receives filtered water from inside the septum elements. It is fitted with an effluent pipe, a capped nipple for introducing precoat slurry, an air-vent valve, and a water-pressure gauge. (See fig. 52.) The collector head is fastened to the top of the filter tank with eight wing nuts and is sealed by a recessed gasket.

c. **SLURRY-FEEDING APPARATUS** (fig. 51). The slurry-feeding apparatus helps to maintain the porosity of the filter cake by continuously adding a small amount of filteraid to the water being filtered. It consists of a slurry tank, a float chamber, a slurry agitator, and weir box.

(1) The slurry tank is a reservoir and agitation chamber for the filteraid slurry. Filtered water enters the slurry tank through an orifice in the bottom of the weir box. (See fig. 52.) Filteraid slurry enters the float chamber through a constant-head orifice in the side of the tank.

(2) The float chamber receives slurry from the slurry tank and

* The most satisfactory septum element is the rubber type. The plastic tube wound with wire (fig. 53) is more easily damaged and clogged, but is easier to obtain. A final decision as to type element to be supplied with pack equipment has not been made.

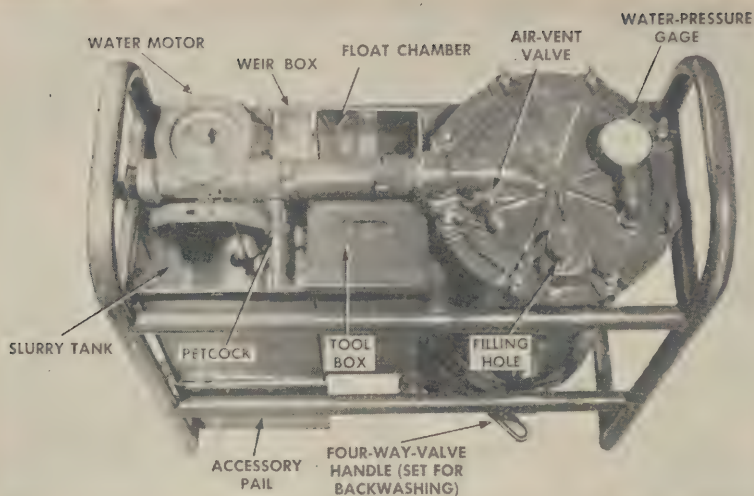


Figure 52. Filter assembly of pack diatomite unit.

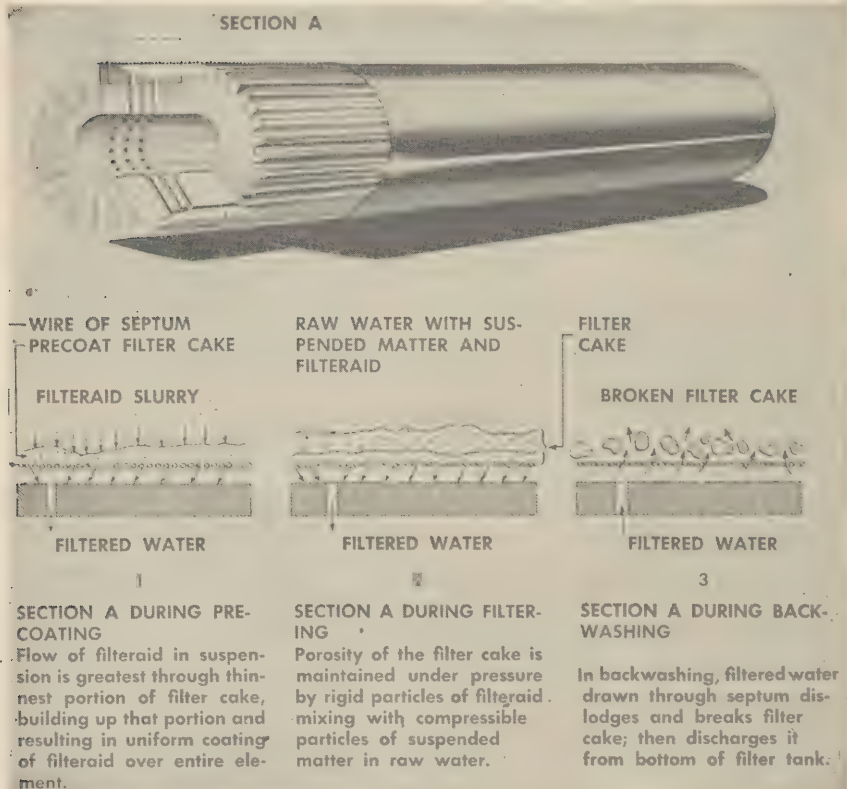


Figure 53. Plastic septum element with section removed.

filtered water from the overflow weir. A float valve in the chamber admits the slurry but closes to prevent air entering the pump suction line.

(3) The slurry agitator keeps the filter aid from settling to the bottom of the slurry tank. It consists of a water motor, a shaft, and a small impeller.

(4) The weir box provides a constant supply of water to the slurry tank. Water flows from the weir box to the slurry tank through a small orifice, and overflows into the float chamber over the weir.

d. PUMP.* The self-priming single-stage centrifugal-type pump draws unfiltered water and discharges it through the unit. It has a maximum capacity exceeding 30 gpm against a total head of 25 feet.

a. ENGINE.¹ The engine drives the pump through a direct connection.

77. Auxiliary Equipment

a. TANKS.² There are four fabric tanks for pretreating raw water, each with a 450-gallon operating capacity. Eight wood or aluminum staves are provided to support each tank. Each tank has a fabric cover. The total weight of one tank complete with staves and cover is about 59 pounds.

b. TESTING APPARATUS. (1) *Chlorine comparator*. The chlorine comparator (fig. 54) is a plastic holder fitted with four permanent glass color standards, indicating 0.5, 1.0, 1.5, and 2.0 ppm of residual chlorine. It has three compartments for viewing test samples, three glass tubes, a plastic stirring rod, and two vials of orthotolidine tablets.

(2) *pH test kit*. The pH test kit (fig. 55) is a glass vial containing 200 strips of test paper. A color chart inside the vial shows the color test strips given when used with water of pH 4.0, 5.0, 5.5, 6.0, 6.5, 7.0, and 8.0.

c. HAND PUMP. A double-acting, 24-inch hand pump is provided for emergency operation of the filter. The pump is fitted with replaceable leather and string cup packing. Used with the filter, the pump produces 5 gpm under normal conditions.

d. ACCESSORIES. (1) *Hose*. There are six 10-foot lengths and two 5-foot lengths of 1¼-inch suction hose. The 10-foot lengths have male and female connections, and the 5-foot lengths have female connections on both ends. Two suction strainers and one sanitary nozzle are provided for the hose.

* See footnote, paragraph 74b.

¹ See footnote, paragraph 74b.

² Not yet accepted as standard issue.



Figure 54. Chlorine comparator.

(2) *Miscellaneous.* A measuring cup for filteraid and alum, a measuring scoop for hypochlorite, a chemical basket, a funnel, a 10-quart collapsible canvas pail, and a filter-element brush* are provided with each unit.

78. Operating Instructions

a. METHODS OF OPERATION. Raw water may be coagulated and settled (pretreated) before filtering or it may be filtered direct. In pretreatment, raw water is pumped into fabric tanks where ammonium alum, and, if necessary, soda ash are added to form a floc, which settles and removes suspended material. After the floc has settled, the treated water is filtered. In filtering direct, raw water is pumped directly to the filter. *This method should be used only where the source is exceptionally clear or in emergencies.*

b. PRETREATING WATER. Before filtering turbid or colored raw water, the following must be done:

* No brush provided if rubber filter elements are used.

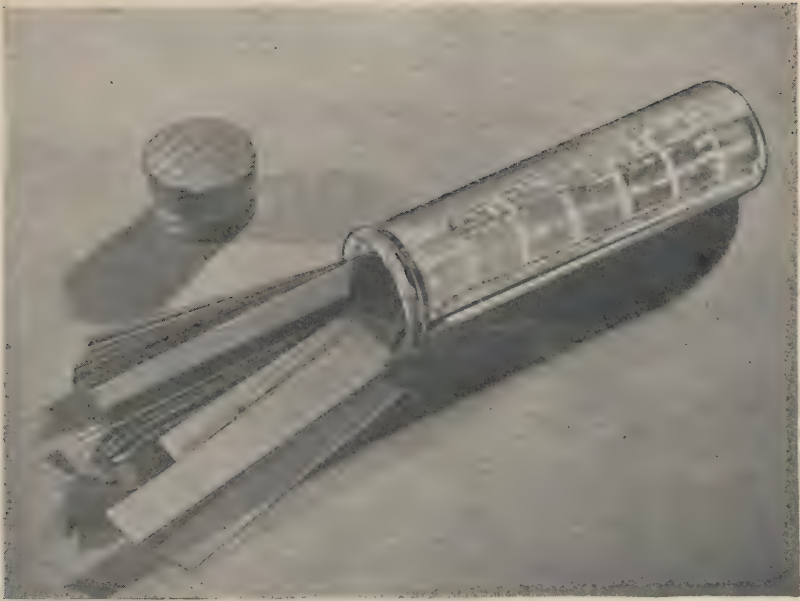


Figure 55. The pH test kit.

(1) Set up one 500-gallon tank on leveled spot near raw-water source.

(2) Connect hose from pump suction to raw water. Put strainer on end of suction hose and submerge in water. Connect hose from pump discharge to tank. Prime pump.

(3) Perform first echelon maintenance on pump and engine assembly and start engine. (See instructions furnished with equipment.)

Note. Remove cork sealing ring from air cleaner (fig. 56), attach air cleaner to carburetor intake, and open oil breather plug. (See fig. 57.)

(4) Direct pump discharge along wall of tank so water swirls inside tank.

(5) Determine pH of raw-water, optimum pH, and a alum and soda-ash dosage. (See par. 58.)

(6) Place lump alum and soda ash, if required, in chemical feed basket, and hang basket in path of pump discharge.

(7) Dissolve two level scoops of hypochlorite in one cup of water and pour solution into tank while it is filling.

(8) Add 1/6 measuring cup of activated carbon if water has unpleasant taste or odor.

(9) Set up two more tanks in leveled places beside first tank.

(10) Take pH of water being treated. If pH is above optimum, reduce soda ash in chemical feed basket and add alum until pH

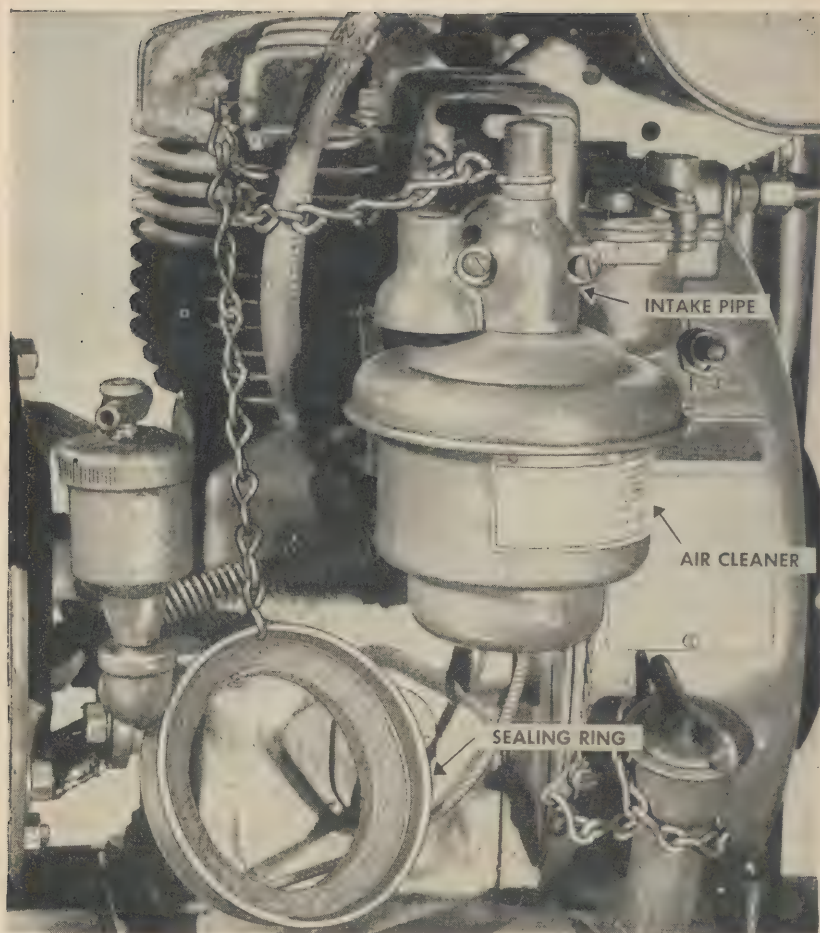


Figure 56. Pump and engine for pack diatomite water purification unit. Cork sealing ring removed and air cleaner attached to intake pipe.

is at optimum. If pH is below optimum, add soda ash to bring pH to optimum.

(11) When first tank is full, fill second tank as described in (4), (6), (7), (8), and (9) above. Use same chemical dosage determined for first tank.

(12) Before filtering water from settling tanks, allow it to settle at least 20 minutes. Check to see that chlorine residual is 1.0 ppm or more.

(13) *Operating precautions.* (a) Place suction strainer in bucket or tie it to a stake to keep it out of mud and silt in stream bottom.

(b) Read equipment operating instructions before starting pump engine.

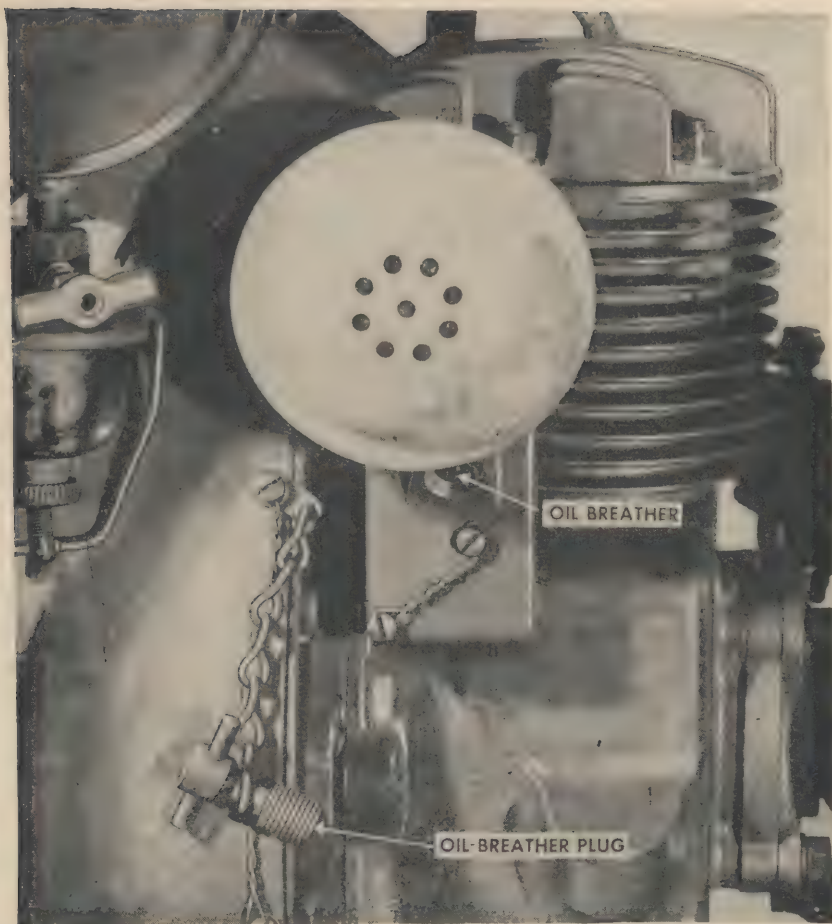


Figure 57. Oil-breather plug unscrewed.

(c) If the pH is above 7.0, little or no soda ash is required for flocculation. The exact proportion of soda ash to alum to be added to each tank must be determined by trial for each new water source.

(d) If soda ash is used, add it in the same basket with the alum. When using soda ash in colored waters, the pH value must not be raised above 6.0 since such values may cause a color fixation.

(e) Water should be allowed to settle in pretreatment tanks as long as possible, because the longer it settles the faster it can be filtered. Where operations continue at one water point for several days, all available tanks should be used for settling water overnight and during idle periods.

c. FILTERING WATER. The following procedure is necessary in filtering pretreated or raw water to produce potable water.

(1) Connect filter assembly to pump (fig. 49), put strainer on suction hose, and run hose (fig. 49) to pretreated or raw water.

(2) Connect a hose to filtered-water outlet on filter section, and run to waste near filtered-water storage tank.

(3) Set four-way valve in neutral position. (See fig. 58.)

(4) Dissolve a scoop of hypochlorite in enough water to fill filter shell (about 3 gallons) and pour this water into filter shell through filling hole. (See fig. 52.) Allow solution to stand for at least 10 minutes to disinfect filter.

(5) Prepare filteraid slurry by mixing $1\frac{1}{2}$ measuring cups of filteraid in approximately $\frac{1}{2}$ gallon of water.

(6) Open four-way valve and drain at least $\frac{1}{2}$ gallon of chlorinated water from filter shell. Refill shell with filteraid slurry.

(7) Fill slurry tank and suction well with raw water to level of connecting hole between the two, and add one cup of filteraid and a pinch of hypochlorite to slurry tank.

(8) Start engine.

(9) Turn four-way valve to filtering position. (See fig. 58.)

(10) When water is delivered, open air vent on filter (fig. 52), and run filter discharge to waste until effluent water is clear; 30 seconds is usually enough.

(11) Open feed-tank petcock (fig. 52), so water in weir box is just flowing over weir into float chamber.

(12) Discharge clear water into 500-gallon storage tanks.

(13) Add hypochlorite to filtered-water storage tank as needed to bring chlorine residual to 1.0 ppm.

(14) Filtering may be continued until flow drops to one-third original flow or pressure gauge on filter head reads 35 psi.

(15) *Operating precautions.* (a) The bottom face of the suction strainer should be kept parallel to and about 6 inches above the bottom of the settling tank. Do not allow sludge to be drawn into strainer. A rock may be tied to strainer to hold it near the bottom of the tank.

(b) If four-way valve leaks during disinfection so septum elements in filter shell are not completely covered with chlorinated water, refill filter shell.

(c) Slurry-feed requirements vary widely for different waters. Generally 1 cup of filteraid is sufficient for initial slurry, and one cup is added to feed tank for each succeeding filter run. Extremely turbid water may require three cups of filteraid. Slurry feed may be discontinued for very clear pretreated water or for raw water from sources such as clear mountain streams.

d. BACKWASHING FILTER. Whenever filtration is interrupted, the following procedure is used for clearing filter cake from elements:

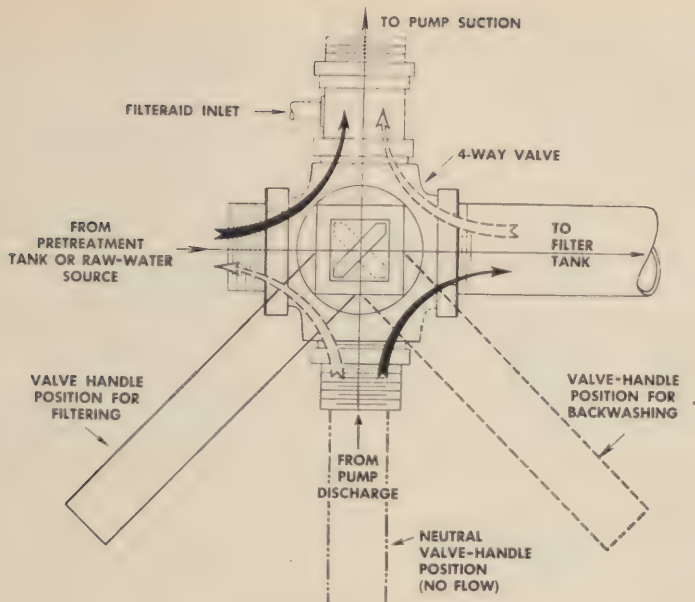


Figure 58. Positions of four-way-valve handle.

(1) Submerge effluent hose in filtered water, swing four-way valve handle to neutral position (fig. 58), and run suction hose to waste.

(2) Swing four-way-valve handle to backwashing position as shown in figure 58.

(3) When discharge is clear, no more filter cake is being cleaned from septum elements. Remove effluent hose from tank to admit air to filter shell and stop engine when it begins to race.

(4) Recharge filter for new run by filling shell with slurry made from filtered water mixed with $1\frac{1}{2}$ cups of filteraid.

e. SPECIAL AND EMERGENCY OPERATION. (1) The filter assembly of the diatomite unit can be used to replace the sand-filter assembly of the portable purification unit. (See fig. 42.) Connect the pumping and treatment assembly of the portable unit to the diatomite filter assembly the same way the pump and engine assembly of the diatomite unit is connected. (See fig. 49.) Chemical feed tanks on the pumping and treatment assembly are not used.

(2) The hand pump is used for emergency operation. Connect its lower or suction inlet to the pump suction connection on the filter and its upper or discharge outlet to the pump discharge connection. (See fig. 49.) Two or three operators should work this pump in shifts. No slurry feed is required when the hand pump

is used. The flow through the unit must be continuous to prevent the filter cake dropping away from the elements.

79. Maintenance of Filter

a. PLUGGED SEPTUM ELEMENTS. Septum elements may eventually become plugged with foreign matter. Plugging is indicated when filter-head pressure is abnormally high at the start of a series of runs and filter output is below normal. The elements and tanks should be scrubbed and disinfected at the slightest indication of plugging. Clean the wire elements by scrubbing them with a brush. Disinfect the elements and the filter tank in the same way as at the start of filter operation. (See par. 78*c*(4).)

b. DAMAGED SEPTUM ELEMENTS. (1) Damaged septum elements must be removed and replaced if possible. If no spare element is available, plug the opening in the filter head as follows:

(*a*) Remove damaged element and tie rod.

(*b*) Replace element-cap nut on tie rod.

(*c*) Reverse tie rod so nut is on top and place element cap and gasket on it.

(*d*) Screw tie rod into filter head until element cap seals off opening. Check gasket for proper seating.

(2) This expedient repair reduces filter capacity by 25 percent. If used on the 50-gpm diatomite filter, filter capacity is reduced only approximately 7 percent.

Section IV. WATER PURIFICATION EQUIPMENT, DIATOMITE, PORTABLE, 50-GPM

80. General

a. DESCRIPTION. The water purification equipment, diatomite, portable, 50-gpm, consists of a pressure filter, diatomaceous slurry-feeding apparatus, precoat recirculation tank, five gasoline-engine-driven pumping assemblies, and auxiliary equipment including a chemical basket, four 3,000-gallon fabric tanks, water supply equipment chest, hose, and measuring cup. (See ASF Supply Catalog ENG 2.) Figure 59 shows the filter assembly, precoat tank, and one pump and engine assembly in operating position.

b. PHYSICAL CHARACTERISTICS. Physical characteristics of the equipment are given below:

| | Height (inches) | Diameter or length and width (inches) | Weight (pound) |
|---|--------------------|--|-------------------|
| Filter assembly | 46 | 24 | 300 |
| Pump and engine assembly, complete with standard frame mounting | 28 | 21 by 17 | 175 |

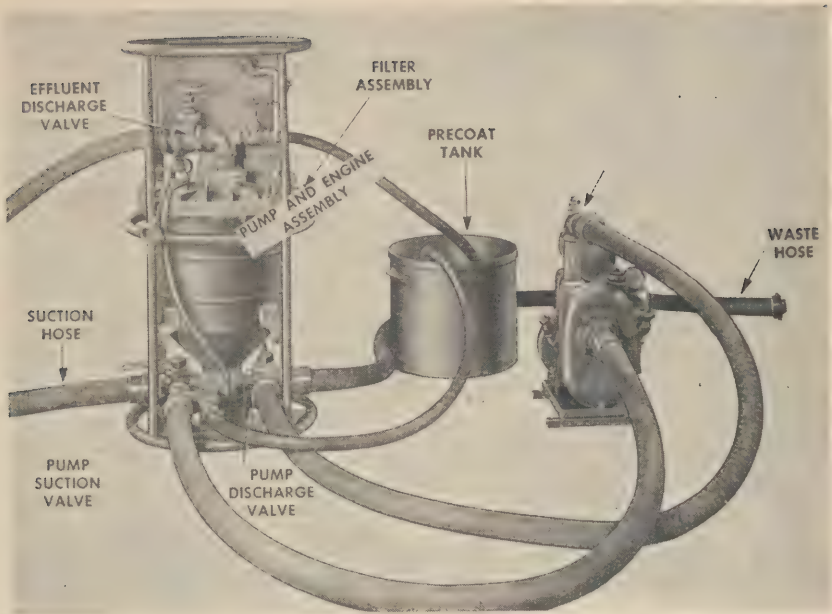


Figure 59. Filter and pump and engine assemblies of portable diatomite water purification unit.

c. **OPERATING CHARACTERISTICS.** A three-man detail is required for continuous operation, including one operator, one man to batch and pretreat water, and a relief operator. For planning purposes, the average amount of water treating chemicals used per 1,000 gallons of water is $\frac{3}{4}$ pound of alum, $\frac{1}{4}$ pound of soda ash, $\frac{1}{2}$ ounce of chlorine, and 1 pound of diatomaceous-silica filteraid. It must be remembered that more or less chemicals may be required, depending on the water source used.

81. Use

a. **PURPOSE.** The purpose of the 50-gpm diatomite equipment is to provide potable water for troops in the field.

b. **CAPABILITIES.** The diatomite filter removes all amoebic cysts and the cercariae of the schistosome. If raw water is coagulated and settled in advance, the diatomite filter delivers 60,000 gallons per-hour day of clear, potable water under all conditions. The complete equipment with supplies for filtering 1,200,000 gallons of water can be transported in one $2\frac{1}{2}$ -ton truck.

c. **LIMITATIONS.** This unit has the same limitations given for the pack units. (See par. 75c.)

82. Functioning

a. FLOW. (1) *During production of filter water.* The centrifugal pump draws unfiltered water through the 2-inch suction hose and pump suction valve, past the filteraid-slurry inlet, and into the pump. (See fig. 60.) The pump impeller mixes the unfiltered water and slurry and discharges the mixture through the pump discharge valve to the baffle chamber at the bottom of the filter shell. The water rises uniformly in the shell, and filters horizontally through the septum elements. In passing through the elements, the water deposits a layer of filteraid and impurities on the elements. This layer or filter cake removes suspended matter from the water passing through it. The filtered water passes through the collecting head and effluent discharge valve to the filtered-water tank. Unfiltered water is bled from the filter shell to the slurry-feeding apparatus where it operates a small water motor and replenishes the slurry added to the raw water.

(2) *During backwashing.* The direction of flow is reversed during backwashing (fig. 61) by the pump discharge and pump suction valves. Filtered water enters the collecting head through the effluent discharge valve and flows out through the septums in reverse. It dislodges the filter cake and carries it out the pump

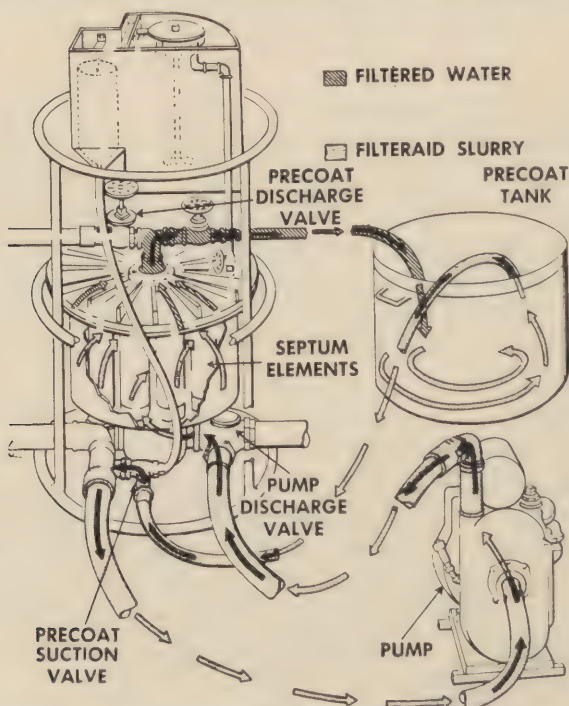


Figure 60. Flow diagram of water during production of filtered water in portable diatomite unit.

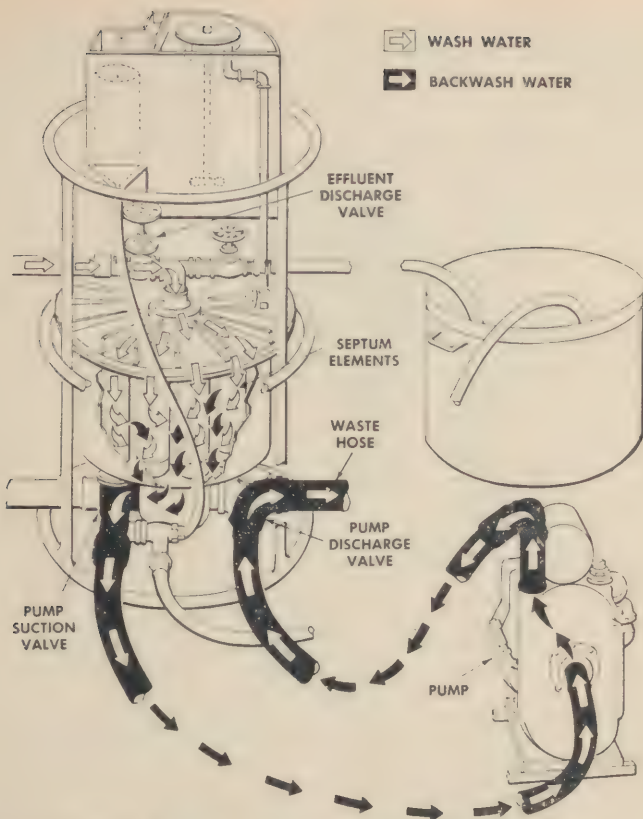


Figure 61. Flow diagram of water during backwashing of portable diatomite unit.

suction valve into the pump. The pump discharges the water to waste.

(3) *During precoating.* (a) During precoating (fig. 62) which always precedes the production of filtered water, the initial layer of filteraid necessary to remove suspended matter from the water is deposited on the filter elements. Filteraid slurry is drawn from the precoat tank through the precoat suction valve and into the pump. The slurry is discharged from the pump through the pump discharge valve to the bottom of the filter shell. As the slurry rises in the shell, a uniform layer of filteraid is deposited on the septum elements. The filtered water returns to the precoat tank through the precoat discharge valve.

(b) At the start of the precoat operation, some of the filteraid passes through the septum elements and returns to the precoat tank. However, after 30 seconds of precoating, the filter cake is built up enough to retain all of the filteraid, and clear water then returns to the precoat tank.

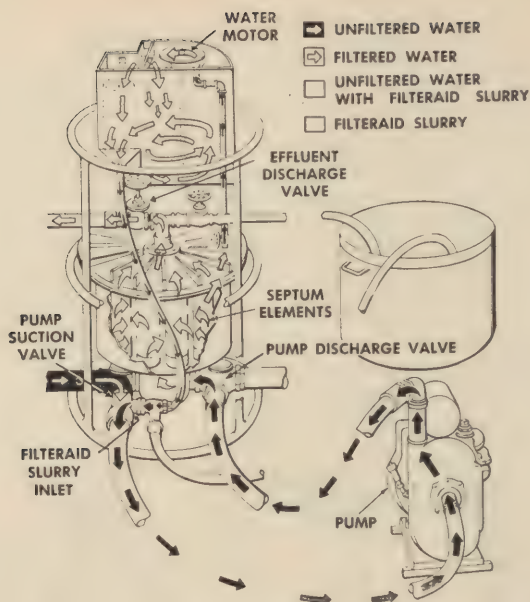


Figure 62. Flow diagram of water during precoating of portable diatomite unit.

b. **FILTER.** The filter (fig. 63) removes suspended matter from the water. It consists of 14 septum elements, an aluminum collecting head, and a stainless-steel shell. Except for differences in size, the filter and septums are similar to those described in paragraph 76b.

c. **SLURRY-FEEDING APPARATUS.** The slurry-feeding apparatus (fig. 63) helps to maintain the porosity of the filter cake by continuously adding a small amount of filteraid to the water being filtered. It consists of a slurry tank, float chamber, slurry agitator, and weir box similar to those described in paragraph 76b.

d. **PUMPS.** The centrifugal self-priming single-stage pumps are capable of delivering continuously a minimum of 55 gpm against a total head of 50 feet, of which 15 feet may be suction. The pumps produce 100 gpm at low heads when fitted with 2-inch hose.

e. **GASOLINE ENGINES.** A 2-hp engine drives each pump through a direct connection. For technical data on the engines, see TM 5-500.

f. **PRECOAT TANK.** The aluminum cover for the slurry-feeding apparatus serves as a precoat tank. (See fig. 59.) During pre-coating the tank contains the precoat slurry. The precoat slurry is circulated between the tank and the filter shell by two 1-inch hoses. The precoat discharge hose may be used to fill canteens or other small containers when the filter is operating.

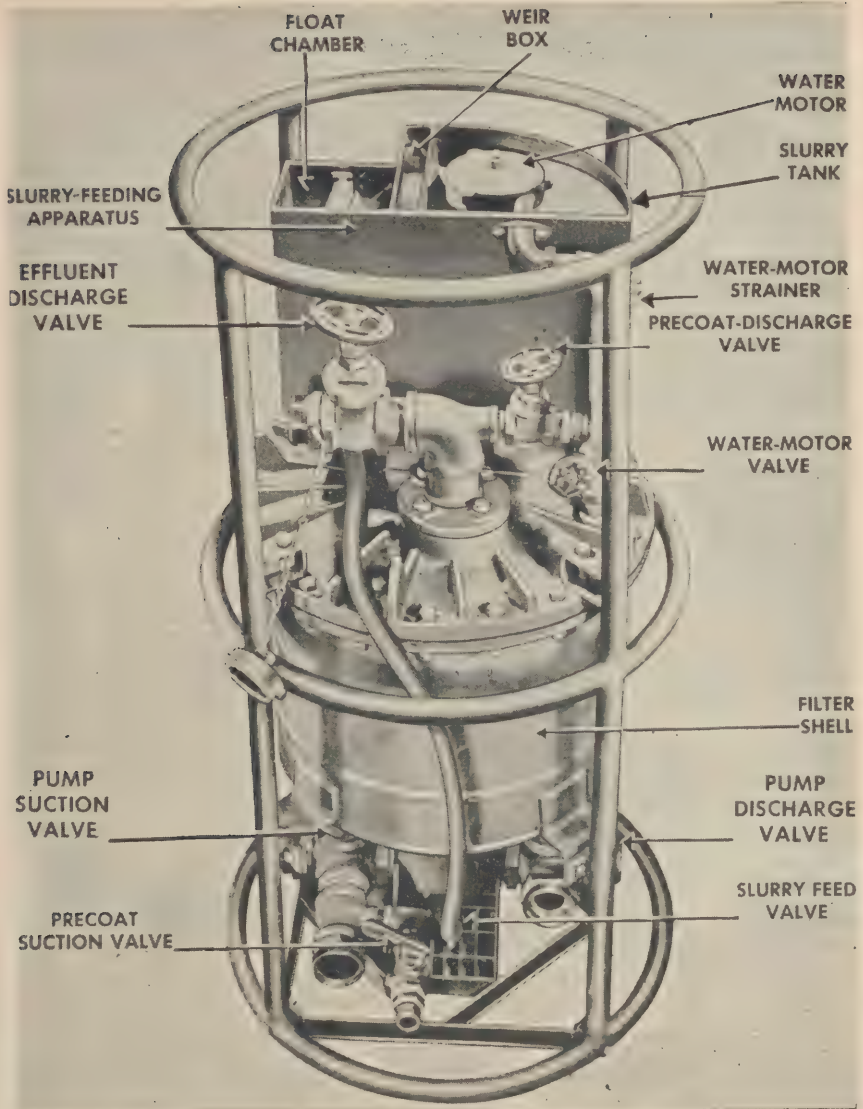


Figure 63. Filter assembly of portable diatomite unit.

83. Auxiliary Equipment

a. **CHEMICAL BASKET.** The chemical basket (fig. 64) has three compartments for introducing chemicals into the water. The largest compartment holds 8 pounds of alum; the next largest, 6 pounds of soda ash; and the smallest compartment, 6 ounces of HTH. The alum and soda-ash compartments are marked off with wire rings for estimating amounts of chemicals in the basket. Two pounds of chemical are contained between each ring.



Figure 64. Chemical basket.

b. FABRIC TANKS. Each diatomite set has four 3,000-gallon fabric tanks for pretreating raw water or storing filtered water. The tanks are $11\frac{1}{2}$ feet in diameter and $4\frac{1}{2}$ feet high. Wooden staves for support and a fabric cover are issued with each tank.

c. CHEST, WATER SUPPLY EQUIPMENT. The chest contains the items shown in the loading plan. (See fig. 65.)

d. HOSE. In addition to the light discharge hose provided in the chest, each set has twenty 10-foot lengths of 2-inch rubber suction hose with male and female connections.

e. MEASURING CUP. The measuring cup is $5\frac{1}{2}$ inches in diameter and $6\frac{1}{2}$ inches high. Filled level it holds $1\frac{1}{4}$ pounds of dry filteraid or the quantity required for one precoat-tank or slurry-tank charge.

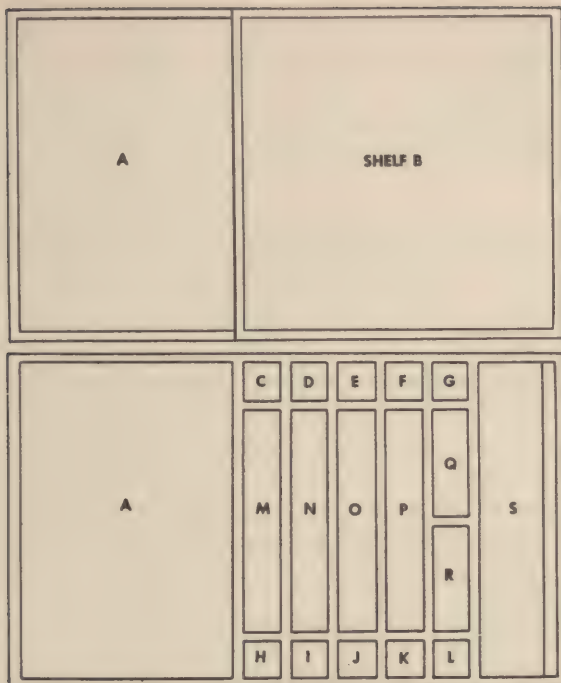


Figure 65. Water supply equipment chest.

f. TEST EQUIPMENT. The standard comparator (par. 57) is used to determine pH and residual chlorine.

84. Operating Instructions

a. METHODS OF OPERATION. Raw water may be coagulated and settled before filtering, or filtered direct. (See paragraph 78*a* for a brief discussion of the two methods.) Unless the source is exceptionally clear, water must always be pretreated.

b. PRETREATING WATER. Before filtering raw water containing turbidity or color, the following must be done:

(1) Set up 3,000-gallon tank on leveled spot near raw-water source.

(2) Connect hose to two pump and engine assemblies with suction screens in raw water and discharge hoses over side of tank. Prime pumps.

(3) Perform first echelon maintenance on each pump and engine assembly and start each engine. (See instructions furnished with equipment.)

(4) See figure 37 for instructions if pump fails to deliver water after 2 or 3 minutes.

(5) Direct pump discharge along wall of tank so water swirls inside tank.

(6) Determine pH of raw water, optimum pH, and alum and soda-ash dosage. (See par. 58.) Soda ash may not be required.

(7) Place twice the amount of coagulant chemicals required (computed in (6) above) and three heaping tablespoons of HTH in chemical basket, and hang basket in raw water. (See fig. 6 and par. 33.)

(8) After chemicals begin to dissolve, add about 1/6 measuring cup of activated carbon if water has unpleasant taste or odor.

(9) Set up two more tanks in level place beside first tank.

(10) Take pH of water being treated. If pH is above optimum, reduce soda ash in chemical basket and add alum to bring pH to optimum. If pH is below optimum, add soda ash to bring pH to optimum.

(11) When first tank is full, repeat steps (5), (7), and (8) for other settling tanks.

(12) Before filtering water from settling tanks, allow it to settle at least 20 minutes. Check to see that chlorine residual is not less than 1.0 ppm.

(13) Operating precautions.

(a) See paragraph 78b(13) (a) through (e).

(b) The position of the chemical basket in the tank determines how fast the chemicals dissolve. They dissolve most rapidly when placed directly in the stream of water from the hose. When each tank is half full, operators should remove the chemical basket and note the amount of chemicals dissolved. If the chemicals are dissolving too rapidly, the basket should be moved away from the stream of water. *The efficiency of settling depends on adding the proper amount of coagulant chemicals.*

c. PRECOATING FILTER ELEMENTS. Before filtering can begin, the filter septums must be precoated by the following method:

(1) Connect filter assembly to a pump and engine assembly and arrange precoat tank as shown in figure 59.

(2) Connect suction hose from filter to settling tanks or raw-water source.

(3) Run hose from effluent valve (fig. 59) to filtered-water storage and from pump discharge valve (fig. 59) to waste.

(4) Close effluent valve (fig. 59) and set pump discharge valve in backwash position and pump suction valve in filter position. (See fig. 66.) Close precoat suction valve and slurry-feed valve. (See fig. 63.)

(5) Put one full measuring cup of filteraid (1¼ pounds) into slurry tank and one into precoat tank.

(6) Prime pump and start engine as described in b(3) above.

Note. If raw water is being filtered, it need only be wasted until pump is delivering a full stream of water.

(7) Run first water from treatment tanks to waste until no more sludge is discharged; this takes about $\frac{1}{2}$ minute.

(8) Fill precoat tank and slurry-feeding apparatus from waste hose. Add one teaspoon of hypochlorite to both tanks.

(9) Turn pump suction valve to precoat position and pump discharge valve to filter position. (See fig. 66.)

(10) Open precoat suction and discharge valves. (See fig. 63.)

(11) Allow pump to circulate water from precoat tank to filter until water in precoat tank is clear.

d. FILTERING WATER. The following must be done to produce filtered water:

(1) Open slurry-feed valve and water-motor valve (fig. 63) so water in weir box is just flowing over weir into float chamber.

(2) When water in precoat tank is clear, open pump suction valve to filter position. (See fig. 66.)

(3) Open effluent discharge valve. (See fig. 63.)

(4) Close precoat suction and discharge valves.

(5) Add hypochlorite to filtered-water storage as needed to bring chlorine residual to 1.0 ppm. If raw water is being filtered, water in storage tank must be allowed to stand for $\frac{1}{2}$ hour with a chlorine residual of 1.0 ppm before being dispensed.

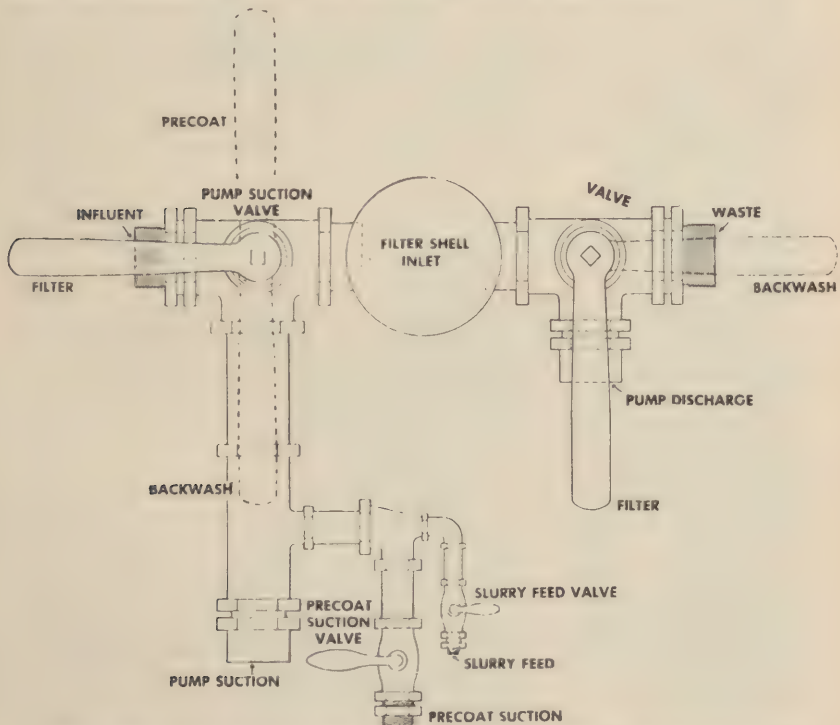


Figure 66. Valve settings for filtering, backwashing, and precoating.

(6) See paragraph 78c (15) (c) for regulation of filteraid flow. It can be reduced to a small amount when filtering water from a clear source.

(7) Filtration may be continued until the rate of filtering drops to one-third starting rate.

e. BACKWASHING FILTER. Whenever filtration is interrupted, the following procedure is used for clearing the filter elements:

(1) Submerge end of effluent hose in filtered-water storage tank.

(2) Close water-motor valve. (See fig. 63.)

(3) Turn pump suction and discharge valves to backwash position. (See fig. 66.)

(4) Allow backwash to continue until waste water is clear; 30 seconds is usually sufficient.

(5) Turn pump suction valve to precoat position and pump discharge valve to filter position. (See fig. 66.) Filter is now ready for precoat. However, do not precoat until ready to start next run, and then proceed as in *c* above, except that precoat tank should be less than one-third full of water.

85. Maintenance

a. PLUGGED SEPTUM ELEMENTS. If plugging is indicated (par. 79a), clean septum elements. After cleaning elements, disinfect them by reassembling the filter and circulating a precoat tank of chlorinated water through the filter for 10 minutes. A teaspoon of calcium hypochlorite in the precoat tank provides enough chlorine.

b. DAMAGED SEPTUM ELEMENTS. Damaged septum elements must be replaced by the procedure given in paragraph 79b.

Section V. WATER PURIFICATION UNIT, STATIONARY (KNOCKDOWN-TYPE)

86. General

a. DESCRIPTION. The stationary water purification unit has all the features of a complete water purification plant of the sand-filter type. It consists primarily of a wood-stave settling tank, sand-filter tank, and wash-water tank; two low-lift and two high-lift centrifugal pumps and a wash-water pump; four belt-driven chemical feeders, two venturi tubes, loss-of-head gauge, four chemical-solution tubs, test kit for determining chlorine residual and pH value, piping, and valves. (See ASF Supply Catalog ENG 2.) Figure 67 shows the stationary unit in operation.



Figure 67. Water purification unit, stationary, 50-gpm.

b. **PHYSICAL CHARACTERISTICS.** Total weight of the unit uncrated is 7.1 tons and total cubage is 502 cubic feet. It requires a level area 25 feet by 45 feet for installation. Dimensions of tanks are given below:

| Tank | Weight* (tons) | Height (feet) | Diameter |
|------------------------|-------------------|------------------|----------|
| Settling tank | 17 | 8 | 10' 4" |
| Sand-filter tank | 8 | 8 | 5' |
| Wash-water tank | 17 | 8 | 10' 4" |

* Approximate weight is given for tanks filled to operating height with water.

c. **OPERATING CHARACTERISTICS.** A three-man detail is required for continuous operation, including an operator, an assistant, and a relief operator. For planning purposes, the average amount of water treating chemicals used per 1,000 gallons of water is $\frac{3}{4}$ pound of alum, $\frac{1}{4}$ pound of soda ash, and $\frac{1}{2}$ ounce of chlorine. It must be remembered that more or less chemicals may be required, depending on the water source used.

87. Use

a. **PURPOSE AND CAPABILITIES.** (1) The purpose of the stationary water purification unit is to furnish potable water to semi-permanent installations such as general hospitals, replacement centers, and base section headquarters in communications zones of theaters of operations. It can treat and deliver about 50,000 to 66,000 gallons of water in a 20-hour day and will pump against a total discharge head of 130 feet.

(2) The two low-lift and two high-lift pumps make continuous operation possible, since only one pump of each type is needed to maintain maximum flow. The ability of this unit to remove amoebic cysts and cercariae of the schistosome has not been tested, but municipal practice demonstrates that with proper operation, these impurities can be completely removed.

b. **PERSONNEL.** Efficient operation of this equipment requires intelligent, mechanically inclined personnel with previous training in municipal purification plants.

88. Functioning

a. **FLOW.** (1) *During production of filtered water.* (a) Raw water is delivered to the baffle chambers of the settling tank by one of the low-lift pumps. It flows by gravity from the settling tank to the filter tank, and is drawn from the bottom of the filter tank and delivered to the distribution system or the wash-water tank by one of the high-lift pumps. (See fig. 68.)

(b) Chemical feeders add hypochlorite and coagulant chemical

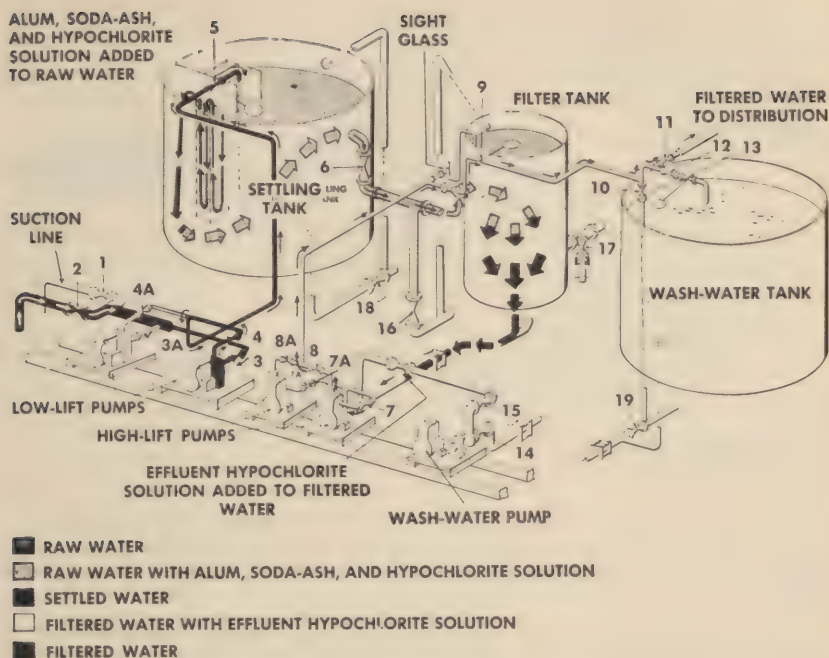


Figure 68. Flow diagram of water during production of filtered water in stationary unit.

solutions on the suction side of the low-lift pump and add hypochlorite solution to the filtered water.

(2) *During backwashing.* When the filter is backwashed (fig. 69), filtered water is drawn from the bottom of the wash-water tank by the wash-water pump, flows into the bottom of the filter tank, rises through the gravel and sand layers, flows into the wash-water trough, and runs to waste.

(3) *During filtering to waste.* During filtering to waste, the water flows through the unit to the high-lift pump in the same direction as during filtering, but is directed to waste from the high-lift pump.

b. LOW-LIFT PUMPS. The low-lift pumps (fig. 67) draw the raw water from the source, mix the water and coagulating chemicals, and pump the mixture to the baffle chamber of the settling tank. A V-belt from the low-lift pump drives the chemical feeders. See figure 79, curve (2), for pump characteristics.

c. CHEMICAL FEEDERS. Two of the four chemical feeders pump hypochlorite solution into the water (prechlorination and post-chlorination); one pumps alum solution; and the other pumps soda-ash solution. These feeders are identical to the hypochlorinator described in paragraph 71e. Check valves on the feeder dis-

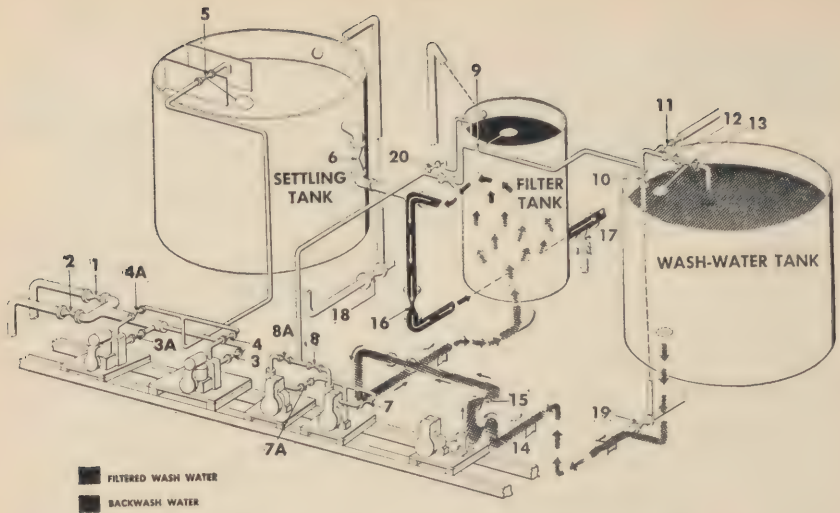


Figure 69. Flow diagram of water during backwashing of unit.

charge lines prevent the low-lift pump from sucking solution from the solution tubs.

d. **SETTLING TANK.** Floc forms and settles out in the settling tank. Rapid and complete settling reduces the impurities going to the filter and prolongs filter runs. The tank contains a baffle chamber, a float-operated valve, and inlet, outlet, and overflow pipe connections.

(1) The baffle chamber receives the water from the low-lift pumps and aids floc formation by giving the water a rolling motion as it passes around the four baffles in the chamber.

(2) The float-operated valve maintains a constant water level in the settling tank.

e. **SAND FILTER.** The sand filter removes turbidity and bacteria from the water. It contains four layers of gravel beneath a 24-inch layer of sand, inlet, outlet, and overflow pipe connections, and a wash-water trough. A float-control valve maintains a constant water level in the filter tank.

f. **WASH-WATER TANK.** The wash-water tank stores clear water for washing the filter. It contains a float-control valve and inlet and outlet piping.

g. **HIGH-LIFT PUMPS.** The high-lift pumps draw water from the bottom of the filter and deliver it to the distribution system or the wash-water tank. They are centrifugal pumps capable of discharging 60-gpm against a 125-foot head.

h. **WASH-WATER PUMP.** The wash-water pump draws water from the wash-water tank and forces it upward through the filter. This pump has a 300-gpm capacity against a low discharge head.

i. GASOLINE ENGINES. Engine data is given in TM 5-2066.

j. VENTURI TUBES AND FLUID-FLOW MANOMETERS. Two venturi tubes with fluid-flow manometers are provided for showing flow of filtered water to the distribution system and wash water to the filter. The tubes and manometers are similar to these described in paragraph 65f.

k. LOSS-OF-HEAD GAUGE. The loss-of-head gauge indicates loss of water pressure across the filter bed. It is a simple U-tube manometer with mercury well, two glass tubes, adjustable scale, and removable head.

89. Operating Instructions

See TM 5-2066 for detailed operating instructions. Filter must be backwashed (fig. 69) when—

- a. Loss-of-head gauge on filter shows 9-inch difference between mercury levels.
- b. Turbidity appears in filtered water.
- c. Unit is shut down for 1 day or more.

90. Plant Records

The characteristics of a water source may vary widely from week to week, requiring various chemical dosages. Carefully kept plant records build up a background of operation experience which simplifies the problems caused by these variations. Record forms should be made up containing the following information:

- a. DURING FILTRATION. (1) *Appearance of floc (good, poor).*
 (2) Satisfactory settling (clear water going to filter).
 (3) Appearance of water in sight glasses.
 (4) Loss of head across filter.
 (5) Fluid-flow manometer readings.
 (6) Chlorine residual at filtered-water discharge.
 (7) pH readings of raw water and filtered water.
 (8) Chemical-feeder settings.
- b. DURING BACKWASHING. (1) *Rate of wash-water flow.*
 (2) Length of wash.
 (3) Appearance of sand bed after wash.
- c. CHEMICALS. Keep a permanent record of chemicals and chemical dosages used each day.

Section VI. WATER PURIFICATION UNIT, HAND-OPERATED, KNAPSACK PACK, FILTER-PAD-TYPE, ¼-GPM

91. General

- a. DESCRIPTION. The knapsack-pack water purification unit con-

sists of a small hand-operated diaphragm pump, double-faced filter disc, base, clamping ring, canvas carrying case, paper filter pads, sterilizing tablets, and accessories. (See ASF Supply Catalog ENG 2.) It is issued as water purification, set No. 1, knapsack pack, $\frac{1}{4}$ -gpm.

b. PHYSICAL CHARACTERISTICS. The filter and pump assembly (fig. 70) weighs 4 pounds and is $4\frac{3}{4}$ inches in diameter and $3\frac{1}{4}$ inches high. The carrying case is about 8 inches by $7\frac{1}{2}$ inches by 6 inches. Complete with case and accessories, the unit weighs about 7 pounds.

c. OPERATING CHARACTERISTICS. Only one man is required to operate the equipment. For planning purposes, two 4-mg Hala-zone tablets per quart of water are required. Under normal conditions, one pair of filters pads will filter 20 quarts of water.

92. Use

a. PURPOSE. The knapsack-pack water purification unit was designed to provide small, isolated troop units, such as parachute troops and patrols, with potable water.

b. CAPABILITIES. The unit produces filtered water of a high clarity from turbid raw water at $\frac{1}{4}$ gpm. It removes amoebic cysts and cercariae of the schistosome from water, and reduces bacteria concentration. It is durable and easy to operate.



Figure 70. Water purification unit, knapsack-pack.

93. Functioning

a. FLOW. Raw water is drawn by the diaphragm pump through the suction strainer and hose and discharged into receiving chambers on top and bottom of the filter disk. (See fig. 71.) The water is then forced through filter pads (fig. 71) on the faces of the filter disk. Filtered water flows from the filter disk to the discharge hose.

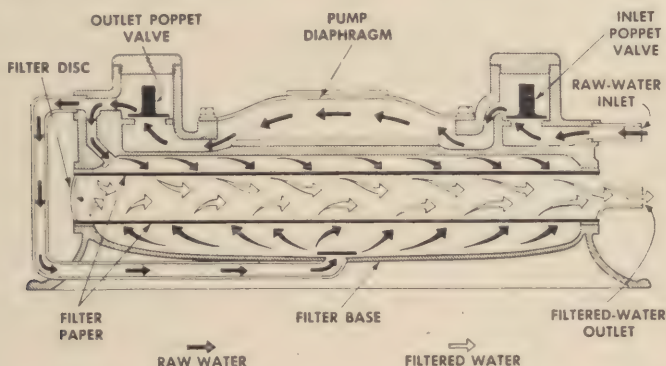


Figure 71. Flow diagram of water through knapsack-pack unit.

b. PUMP. The diaphragm pump draws water to the unit and forces it through the filter to the outlet. It is self-priming and has a capacity of approximately one quart per minute when operated at 70 to 80 strokes per minute. It consists of a fabric reinforced moulded neoprene diaphragm, pump lever and pump link, poppet-type spring-loaded suction and discharge valves, and pressure-relief valve. (See fig. 72.)

(1) The rubber diaphragm forces water from the pump on the down stroke of the pump lever. It is spring-loaded, so it returns by itself after the down stroke, drawing water into the pump.

(2) The hand-operated pump lever and pump link actuate the rubber diaphragm. After each down stroke, they are returned by the diaphragm spring.

(3) The suction or inlet poppet valve (fig. 71) opens on the suction stroke of the pump, permitting raw water to enter the pump. The discharge poppet valve (fig. 71) opens on the discharge stroke of the pump, allowing raw water above and below the filter disk. Springs and disks in the valves are interchangeable.

(4) The pressure-relief valve opens when the water pressure against the filter disk equals 50 psi. This valve consists of a ball and spring, and is located under the hinge of the pump lever.

c. FILTER DISK. The filter element is a flat disk about 6 inches in diameter and $\frac{3}{4}$ inch thick. (See fig. 72.) The top and bottom of the disk are coarse wire screen; a metal ring forms the sides.

Screen and ring are permanently assembled and accommodate 5½-inch-diameter filter pads.

d. **BASE.** The filter base (fig. 72) prevents tipping of the assembly during operation and is a receiving chamber for raw water.

e. **CLAMPING RING.** The clamping ring (fig. 72) holds the pump, filter, and base together. It is lever-operated to permit quick disassembly of these units.

f. **CANVAS CARRYING CASE.** The carrying case (fig. 70) has three pockets for transporting the unit. It is made of water-resistant canvas with built-in stiffeners.

g. **FILTER PADS, CANTEEN STERILIZING TABLETS, ACCESSORIES.**

(1) Each set has 124 pairs of filter pads, each pair capable of filtering at least 20 quarts of water.

(2) Halazone tablets are included for sterilizing canteen water.

(3) Accessories include 5/16-inch rubber tubing, a helically wound suction strainer, and a cork float attached to the strainer.

94. Operating Instructions

a. **PRELIMINARY PREPARATION BEFORE FILTERING.** (1) Remove filter assembly from carrying case, release clamping-ring catch, and separate filter disk from pump and base.

(2) Put one filter pad on top of base, place filter disk carefully on pad, and put a second pad on top face of filter disk.

Note. Smooth surface of filter pads must be against disk. Avoid contaminating smooth side of filter pad or screen of filter disk.

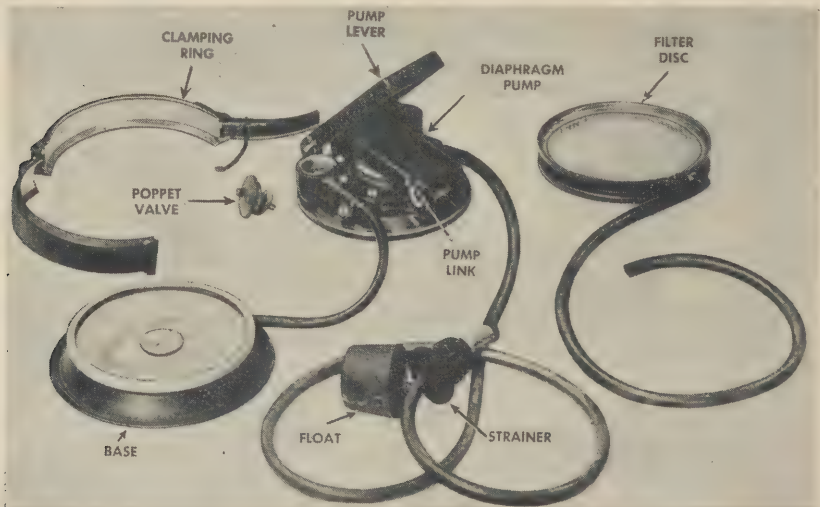


Figure 72. Knapsack-pack unit disassembled.

(3) Place diaphragm pump on top of filter disk and clamp assembly together with clamping ring.

Note. Adjust clamping ring at hinge if too tight or too loose.

(4) Put suction strainer in water source so moss or leaves do not clog strainer.

(5) Check suction hose for tight connection to unit.

b. FILTERING TO CLARIFY RAW WATER. (1) Operate pump lever up and down at maximum of 100 strokes per minute. Decrease pumping rate when pressure-relief valve discharges water.

(2) If water is not delivered after 1 or 2 minutes, check strainer for clogging, suction hose for clogging or loose connection to pump, and poppet-valve caps for leaks.

(3) Receive filtered water in canteens or other container.

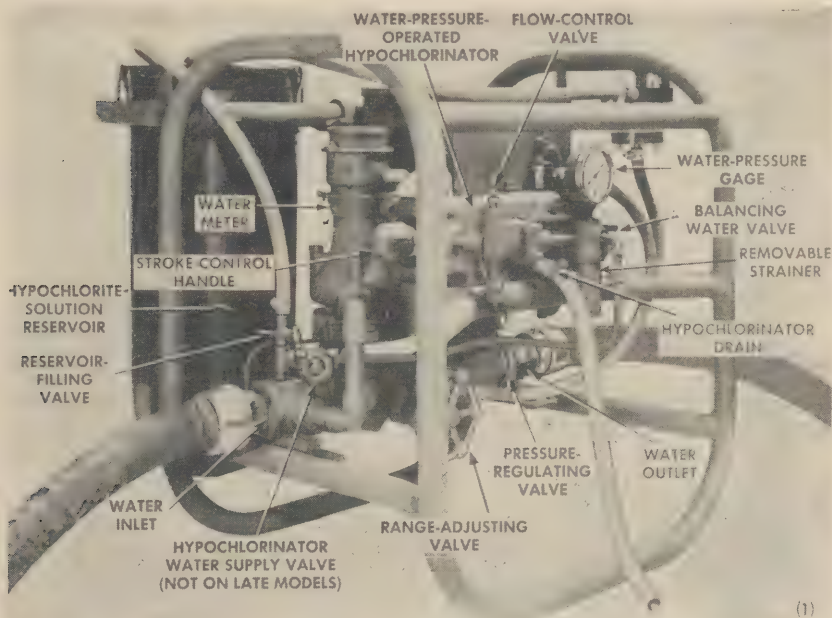
(4) Change to new filter pads when flow gets too small.

(5) Add two Halazone tablets to canteen of water. Water should not be consumed for 30 minutes after tablets have dissolved.

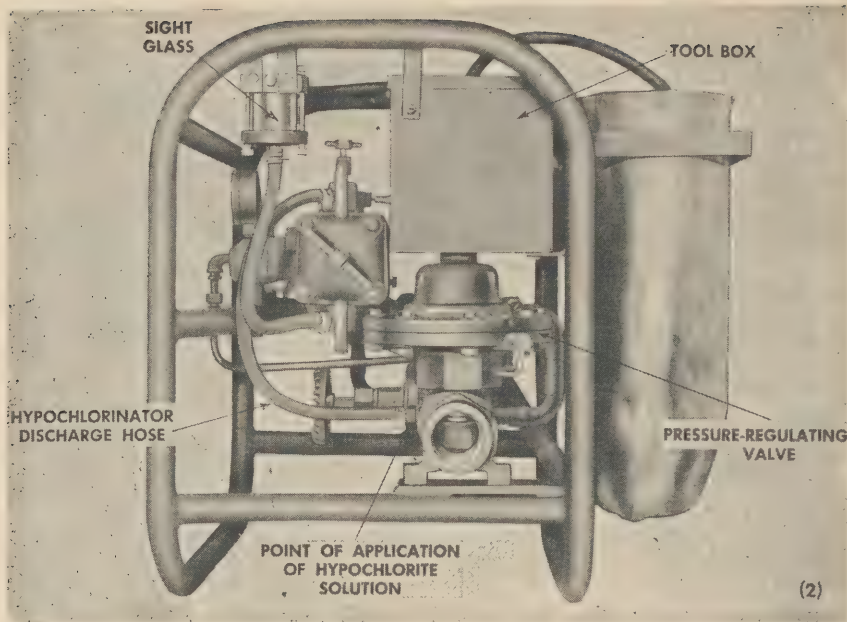
Section VII. HYPOCHLORINATION UNIT, AUTOMATIC, PORTABLE

95. General

a. DESCRIPTION. The portable automatic hypochlorination unit consists principally of a water-pressure-operated hypochlorinator.



① Portable automatic hypochlorinator, 2 = to 100 = gpm.
Figure 73.



② *Portable automatic hypochlorinator, 2 = to 100 = gpm.*
Figure 73 (Contd.).

tor, balancing water valve, water meter, range-adjusting valve, and pressure-regulating valve. (See ASF Supply Catalog ENG. 2.) Figure 73(1) and (2) shows this apparatus.

b. PHYSICAL CHARACTERISTICS. The unit is 26 inches high, 25 inches long, 18½ inches wide, and weighs 165 pounds.

c. OPERATING CHARACTERISTICS. This unit is virtually automatic and requires only one operator under all conditions. For planning purposes, the chemical requirements is ½ ounce of chlorine per 1,000 gallons.

96. Use

a. PURPOSE AND CAPABILITIES. This water-pressure-operated unit is installed in water distribution systems where chlorination alone is needed. Installed in 2-inch pipe or hose, it chlorinates water pumped at rates from 2 to 100 gpm. Installed on a bypass from 4- or 6-inch main (par. 99), it chlorinates flows from 2 to 400 gpm. It pumps hypochlorite solution into the water line, the quantity of solution pumped varying automatically with the amount of water flowing through the pipe. When set for maximum flows expected, the unit proportions the hypochlorite solution for flows down to one-tenth the maximum.

b. LIMITATIONS. (1) Hypochlorinator operation requires a minimum continuous water pressure of 10 psi. Five psi of this

operating pressure is lost because of friction inside the unit and 5 psi is available at the water outlet of the unit.

(2) There is a constant, small wastage of water from the hypochlorinator of the unit. (See par. 97a.)

97. Functioning

a. **FLOW.** The water to be chlorinated flows into the unit through the range-adjusting valve, past the hypochlorite-solution inlet, and out through the pressure-regulating valve. (See fig. 74.) The range-adjusting valve regulates water flow from the main line through the water meter. The hypochlorinator water-supply valve directs a small amount of water from the main line to the hypochlorinator, from which it runs to waste. (See paragraph 99 for flow when unit is used on a bypass.)

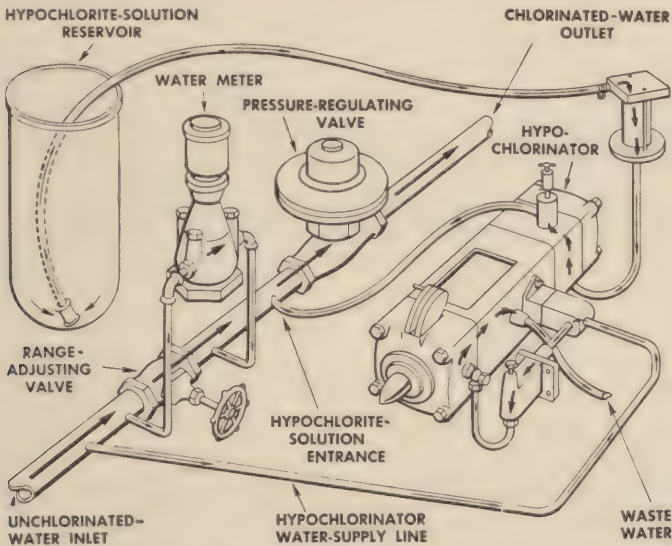


Figure 74. Flow diagram of water through automatic hypochlorinator.

b. **HYPOCHLORINATOR UNIT.** The water-pressure-operated hypochlorinator (fig. 73(1)) pumps hypochlorite solution into the water. The suction stroke of the pump diaphragm pulls hypochlorite solution into the pump head through the intake poppet valve, and the discharge stroke forces it into the main line through the outlet poppet valve. The pump head is identical to that shown in figure 45. The hypochlorinator will pump .0035 gallons of solution per stroke at a stroke-control handle setting at 10. The mechanism of the hypochlorinator is completely described in TM 5-2032. Essential parts are power diaphragm, pump diaphragm,

balancing water valve, and flow-control valve. Their functions are given briefly below.

(1) *Power diaphragm.* The power diaphragm contacts the pump diaphragm through a shaft. The power diaphragm moves forward when water pressure builds upon it and carries the pump diaphragm through its pressure stroke. At the end of the stroke, the water pressure behind the power diaphragm is released and the assembly-return spring returns both diaphragms to their original positions.

(2) *Balancing water valve.* (a) The balancing water valve (fig. 73) aids the hypochlorinator on the pumping stroke by building up behind the pump diaphragm a pressure equal to the waterline pressure. The force built up behind the power diaphragm, then, has only to overcome the resistance of the assembly-return spring to move the pump and power diaphragm forward.

(b) A strainer is located below this valve to protect it. This strainer can be removed for cleaning.

(3) *Flow-control valve.* The flow-control valve maintains a constant water flow to the chamber behind the power diaphragm, regardless of changes in water pressure at the water inlet.

c. *WATER METER.* The water meter closes and opens the valve which causes water pressure to build up behind the power diaphragm of the hypochlorinator. This controls the number of strokes per minute made by the hypochlorinator. The water meter is actuated by water diverted through it from the main line.

d. *RANGE-ADJUSTING VALVE.* The range-adjusting valve controls the speed of the water meter by controlling the amount of water which is diverted through it. Closing the valve increases the amount of water diverted through the meter and increases the speed of the meter; opening the valve has the opposite effect.

e. *PRESSURE-REGULATING VALVE.* The pressure-regulating valve (fig. 74) maintains the 10-psi water pressure necessary for operation. It is a spring-loaded diaphragm valve which will not open unless 10-psi pressure exists under the diaphragm.

98. Operating Instructions for Unit Mounted in a Main Line

After the hypochlorination unit has been installed in a line, it is placed in operation in accordance with instructions given in TM 5-2032.

99. Installation of Unit on a Bypass From a Water Main

a. The portable automatic hypochlorinator can be installed on a bypass from 4- or 6-inch water main. (See fig. 75.) Water is diverted from the main by a gate valve (fig. 75) and through 1-

inch pipe to the unit. The range-adjusting valve is closed on the unit and all the diverted water flows through the water meter. The water leaves the unit through a short nipple threaded into the inlet used for hypochlorite solution during operation. (See par. 98.) With this arrangement, hypochlorite solution is added through a hole in the nipple, the chlorinated water flowing back to the main line through a rubber hose.

b. With the unit on a bypass, operation procedure is the same as for a main line. (See par. 98.) The main-line gate valve is used instead of the range-adjusting valve to control the speed of the hypochlorinator. Solution strength may have to be raised above 1 percent to give the proper chlorine residual.

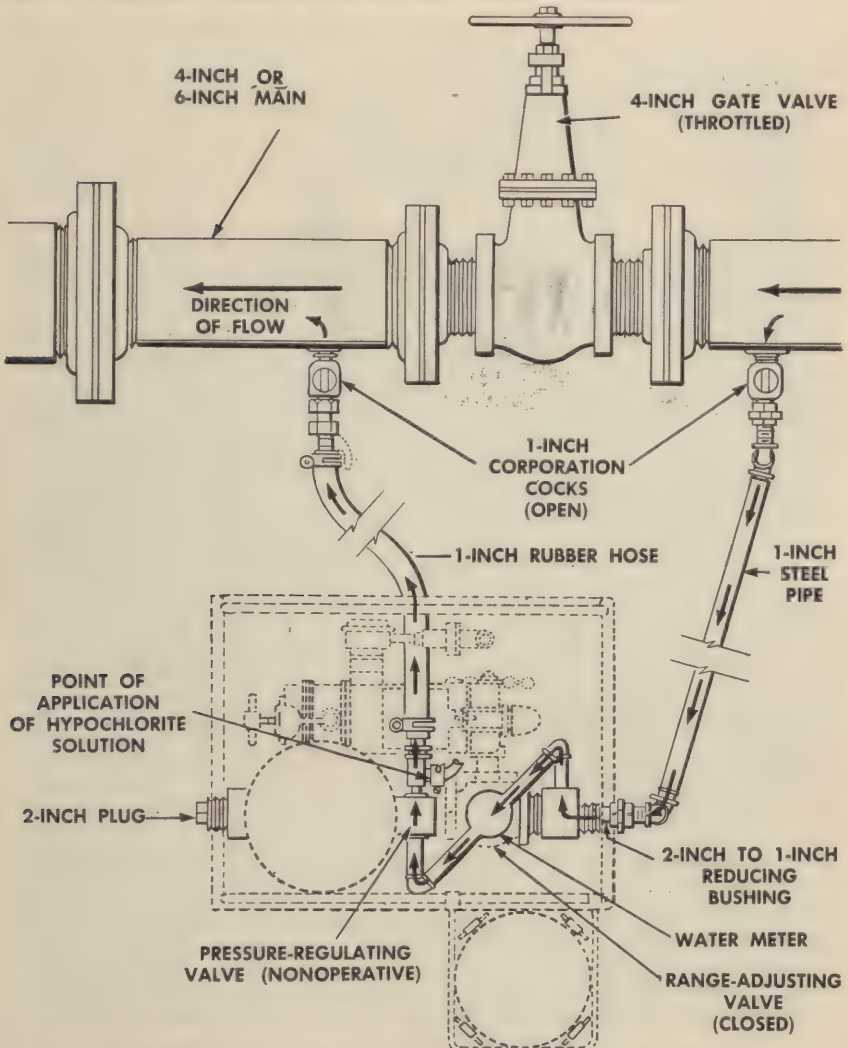


Figure 75. Installation of automatic hypochlorinator on bypass.

Section VIII. PUMPING AND HYPOCHLORINATION UNIT, PORTABLE

100. General

a. DESCRIPTION. The portable pumping and hypochlorination unit consists of a gasoline engine coupled to a 55-gpm centrifugal pump, a belt-driven hypochlorinator, and two tool boxes. (See fig. 76 and ASF Supply Catalog ENG 2.) It is the same as the pumping and treatment assembly described in paragraph 71, except that it has no chemical feed tanks or venturi tube.

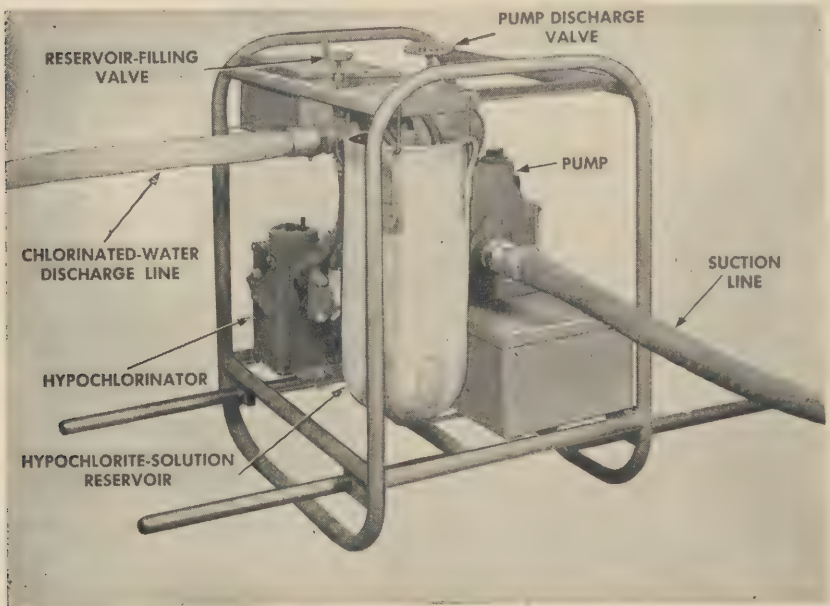


Figure 76. Pumping and hypochlorination unit, 50-gpm.

b. PHYSICAL CHARACTERISTIC. The pumping and hypochlorination unit is 38 inches high, 25 inches wide, and 31 inches long. It weighs 285 pounds.

c. PURPOSE AND CAPABILITIES. The purpose of this unit is to pump and treat water which requires chlorination only. It delivers 50 gpm of chlorinated water against a total head of 50 feet, of which 15 feet may be suction.

101. Functioning

a. FLOW. Water to be chlorinated is drawn through the pump and discharged past the hypochlorite-solution inlet. Flow is the

same as in the pumping and treatment assembly shown in figure 44, except that soda-ash and alum solutions are not added.

b. ENGINE, PUMP, HYPOCHLORINATOR. These units are the same as those described in 71*c*, *d*, and *e*.

102. Precautions

Before operating this equipment, see TM 5-2058 for detailed operating instructions. (See paragraph 72 for special precautions.)

Section IX. PURIFYING WATER FOR SMALL UNITS

103. Bag, Canvas, Water-sterilizing

a. DESCRIPTION. The canvas water-sterilizing bag (fig. 77) (Lyster bag) may be rubber-coated for use in cool climates or porous for use in hot dry climates. The bag is fitted with five small faucets at the bottom, a metal ring with four grommets for suspending the bag at the top, and a cover.



Figure 77. Bag, canvas, water-sterilizing (Lyster bag).

b. PHYSICAL CHARACTERISTICS. The bag weighs 18 pounds and holds 36 gallons of water when filled to within 4 inches of the top. It is sturdy, watertight, and readily collapsible for packing.

c. USE. The bag is used to disinfect raw water for drinking when no other purification equipment is available. Special methods of disinfection are required to destroy amoebic cysts or cercariae of the schistosome. The bag also provides a clean storage tank and convenient dispensing point for water purified by other means.

104. Method of Disinfecting Water in a Lyster Bag

a. BASIC PROCEDURE. (1) Support Lyster bag as shown in figure 77 or in some other way, and fill to 36-gallon mark. If mark is missing, fill to within 4 inches of top.

(2) Draw a small quantity of water from one of the faucets into a canteen cup. Break one calcium hypochlorite ampule into cup and stir until hypochlorite is dissolved. Add sufficient water to fill cups two-thirds full.

(3) Empty hypochlorite solution into bag and stir water in bag with a clean stick until hypochlorite is thoroughly mixed.

(4) After the calcium hypochlorite has been in contact with the water in the bag for at least 10 minutes, wash out the faucets by allowing a small amount of water to run through them onto the ground. Determine the presence of free chlorine in the water by one of the following methods:

(*a*) *Liquid orthotolidin method.* Draw $\frac{1}{2}$ inch of water from a faucet into a clean canteen cup. Add 1 cc of orthotolidin testing solution to the water in the cup. Wait 5 minutes and note color produced. Interpret result as follows:

| <i>Color obtained</i> | <i>Interpretation</i> |
|-----------------------|--|
| No color | Insufficient chlorination. Add more calcium hypochlorite. |
| Canary yellow | Insufficient chlorination. Add more calcium hypochlorite. |
| Deep yellow | Satisfactory chlorination. |
| Orange red | Overchlorinated. Add more water and retest. |
| Bluish green | Alkaline or hard water. Add a few more drops of orthotolidin to get a correct color reading. |

(*b*) *Orthotolidin tablet method.* Remove the inner vial from the testing kit and fill the outer vial to the bottom of the colored band with water from a faucet. The inner vial contains the testing tablets; drop one of these tablets into the sample and shake until dissolved. Note the color produced and interpret as follows:

| <i>Color obtained</i> | <i>Interpretation</i> |
|-------------------------------|--|
| Equal to or darker than band. | Satisfactory chlorination. |
| Lighter yellow than band | Insufficient chlorination. Add more calcium hypochlorite to the water being treated; wait 10 minutes and retest. |
| Orange color | Overchlorinated. Add more water and retest. |

(5) Allow water to stand for 20 minutes after testing, or a total of 30 minutes after adding the calcium hypochlorite, before using it for drinking purposes.

(6) The chlorine comparator (par. 57) can be used to test for the presence of free chlorine. The residual after 10 minutes contact time should be 1 ppm.

b. TO DESTROY AMOEBIC CYSTS. Water containing or suspected of containing amoebic cysts can be disinfected by modifying the basic procedure to increase the residual-chlorine content. This modification is important. First add enough calcium hypochlorite to produce a residual-chlorine content of at least 1 ppm after 10 minutes contact time. (See *a* above.) Immediately add the contents of another ampule of calcium hypochlorite, and allow a further contact period of 30 minutes before distributing the water. This should produce a chlorine residual over 2 ppm. (See par. 41*b*(1)(*b*).)

c. TO DESTROY SCHISTOSOMES. In areas where schistosomes may be present in the water, disinfect all water by adding enough calcium hypochlorite to produce a residual-chlorine content of 1 ppm after 30 minutes contact time. Water containing schistosomes is dangerous to handle (par. 48*d*) as the organisms will penetrate the skin.

d. BOILING. Boiling for 1 minute destroys all disease-producing organisms in the water. This method of disinfection is more certain than chlorination and should be used whenever practicable. After boiling, water must be chlorinated to prevent recontamination.

105. Water Purification Tablets (Halazone)

Water can be purified in the issue canteen with individual water purification tablets. Since these tablets may be supplied in either 4- or 8-mg size, the number of tablets to be added to a full canteen of water varies. Directions given on the containers for these tablets must be followed. Two 4-mg tablets or one 8-mg tablet is required per quart of clear water. If the water is turbid or colored, two of the 8-mg tablets or four of the 4-mg tablets are required to disinfect it. It is imperative that at least 30 minutes elapse after

adding the tablets before drinking the water. If the presence of schistosomes or amoebic cysts is suspected, use at least four of the 4-mg tablets

106. Use of Canteen and Calcium Hypochlorite Ampule

If individual purification tablets are not available, water may be purified in canteens using the same powder (calcium hypochlorite) as is used in the Lyster bag. One calcium hypochlorite ampule is dissolved in a full canteen of water. This strong solution is then used to purify water in other canteens. The cap of a canteen is used as a measure and one canteen capful of this solution is added to each full canteen of water to be treated. The canteens so treated must be well shaken and must not be used until 30 minutes after chlorination. If the presence of schistosomes or amoebic cysts is suspected, two capfuls of the concentrated solution must be used to disinfect clear water; three capfuls for turbid or colored water.

Section X. SUPPLEMENTAL WATER SUPPLY EQUIPMENT

107. Scope

Supplemental water supply equipment is equipment essential for operating a water point; it is not used for actual purification or disinfection of the water. This equipment includes centrifugal pumps, fabric tanks, suction and discharge hose, valve nozzles, valves, pipe fittings, and wrenches. Since pumps, tanks, and hose are easily damaged through improper installation of poor maintenance, a brief description of them and suggestions for their care are included in this section.

108. Centrifugal Pumps

a. TYPES USED. In general, centrifugal pumps used at water points are those which can be readily manhandled and carried in light vehicles. The centrifugal pump now being issued to engineer troops is the Jaeger model 2APS-1. (See fig. 78.) Other models formerly issued and still in service in the field are the Jaeger model 2APS, Barnes model M, Carver model 255, and Red Jacket model M-7M. These pumps have similar capacities to the standard 2APS-1 model. The Novo model KH-2 and the Gorman-Rupp model W52-10 centrifugal pumps are carried in engineer depots and may be used on water points.

b. FUNCTIONING. Centrifugal pumps consist of a pump body, an impeller, a check valve, and a grease seal.

(1) The pump body houses the pump mechanism. It has three

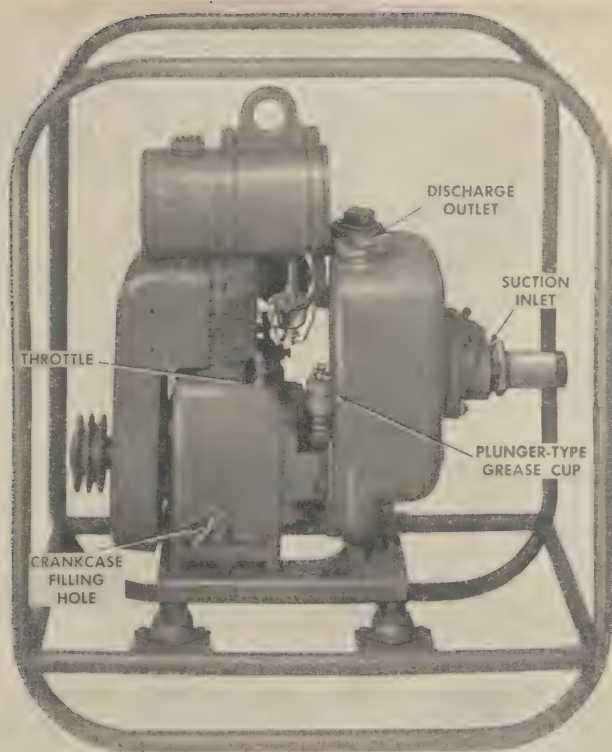


Figure 78. Standard pump and engine assembly.

openings; one for suction, one for discharge, and one for priming.

(2) The impeller spins inside the pump body, creating a suction at the suction opening of the housing and forcing the water out under pressure at the discharge opening. The impeller rotates at about 2,000 rpm. There is .005- to .01-inch clearance between the impeller and the pump body.

(3) The check valve, a heavy rubber flap over the suction opening of the pump, allows water to enter the pump body when the impeller is rotating, but closes to prevent water from being drawn away from the pump body when the impeller stops.

(4) The grease seal prevents water from escaping around the engine driveshaft. It is continuously lubricated during operation by a plunger or screw-down-type grease cup. See proper War Department Lubrication Order for the grease-cup type and lubricant required for different centrifugal pumps.

c. PHYSICAL CHARACTERISTICS AND CAPACITIES. (1) Physical characteristics of these centrifugal pumps are given below.

| Model | Size discharge (inches) | Shipping weight (pound) | Shipping cubage (boxed for export) |
|--------|-------------------------|-------------------------|------------------------------------|
| 2APS-1 | 2 | 350 | 14 |
| KH-2 | 2 | 600 | 20 |
| W52-10 | 2 | 697 | 26 |

(2) A comparison of pump capacities and total head for models 2APS-1 and W52-10 is given in figure 79.

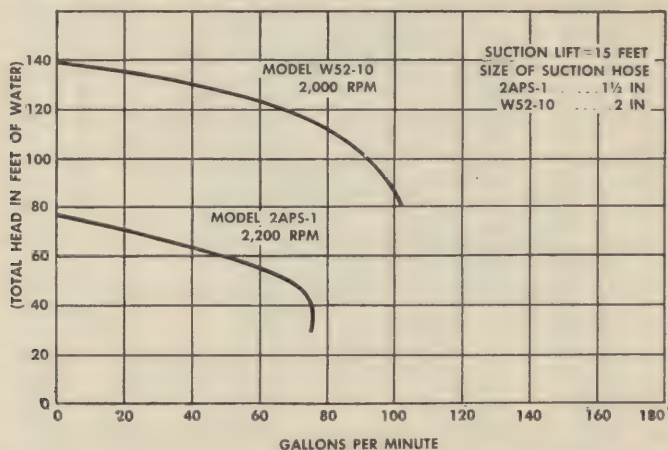


Figure 79. Performance curves for two standard low-capacity pumps.

d. HINTS ON CORRECT PUMP INSTALLATION AND OPERATION.

(1) When installing pump, check to see that (fig. 80)—

(a) Pump is as close as possible to source and not more than 15 feet above source.

(b) Pump is level.

(c) Suction hose drops uniformly from pump to water, and there are no kinks or bends in it which may hold air pockets.

(d) All of suction line is same diameter as suction opening in pump body.

(e) Strainer is at end of suction line.

(f) Pump is primed.

(g) Keep operating speed low to reduce maintenance.

(2) Pump should not be allowed to operate more than 2 or 3 minutes without water running through it. If pump does not produce water when first started, check for—

(a) Air leaks. (See fig. 80.)

(b) Too high suction lift.

(c) Too much discharge head. Do not pump against head greater than that for which pump was designed. (See fig. 79.)

e. MAINTENANCE. See War Dept. Technical Manual for repair instructions. (See FM 21-6.) If proper care is taken of pump, little maintenance is necessary.

PUMPS WEAR OUT QUICKLY ...

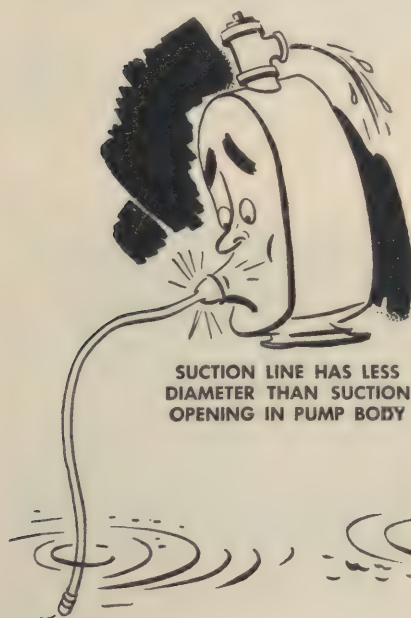
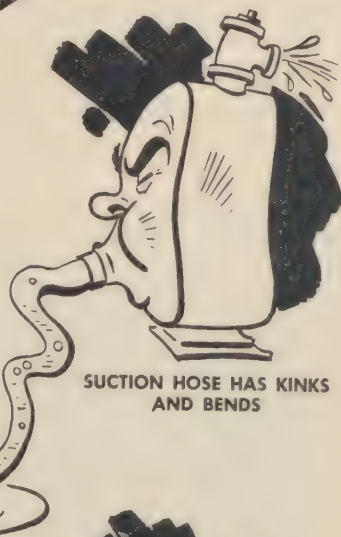
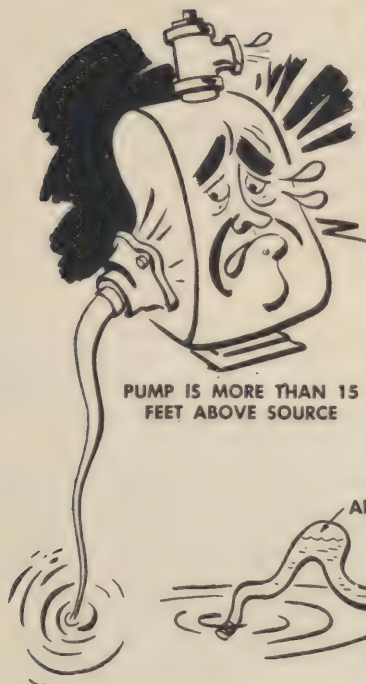
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Figure 80. Hints for care of pumps

109. Fabric Tanks

a. GENERAL. Fabric tanks, either 500- or 3,000-gallon capacity, are made of canvas or glass fabric. Erected, the 3,000-gallon tanks are about $4\frac{1}{2}$ feet high and $11\frac{1}{2}$ feet in diameter; 500-gallon tanks are 3 feet high and 6 feet in diameter. The 500-gallon tank is issued with the 15-gpm diatomite water purification unit.

b. TYPES IN USE. (1) *Canvas tanks.* The 3,000-gallon canvas tank is the most common fabric tank. It is issued with a cover, 20 staves, 4 support ropes, and weighs about 390 pounds in all. There are 2 models of canvas tanks, the old and the new or inclosed-stave type.

(a) The old-type canvas tank has three 2-inch female-threaded outlets spaced equally around the sides near the bottom of the tank. Each stave is notched at one end and is held in place against the tank by four canvas patches riveted to the tank.

(b) The new or inclosed-stave type canvas tank (fig. 81) has shorter staves than the old-type tank. The staves are held in place against the tank by long canvas pockets. The tank has two 2-inch outlets on opposite sides near the bottom of the tank, and a metal thimble in the end of each support rope. (See fig. 81.) It is issued with ground cloth, cover, 20 staves, and 4 support ropes.

(2) *Glass-fabric tanks.* Glass-fabric tanks in both 500- and 3,000 gallon sizes are made of glass fabric impregnated with GR-S synthetic rubber or Vinylite.

(a) The GR-S rubber-coated 3,000-gallon tank (fig. 82) is similar in appearance and weight to the old-type canvas tank. It has 2 outlets opposite each other in the bottom, and is issued with ground cloth, cover, 20 staves, and 4 support ropes.

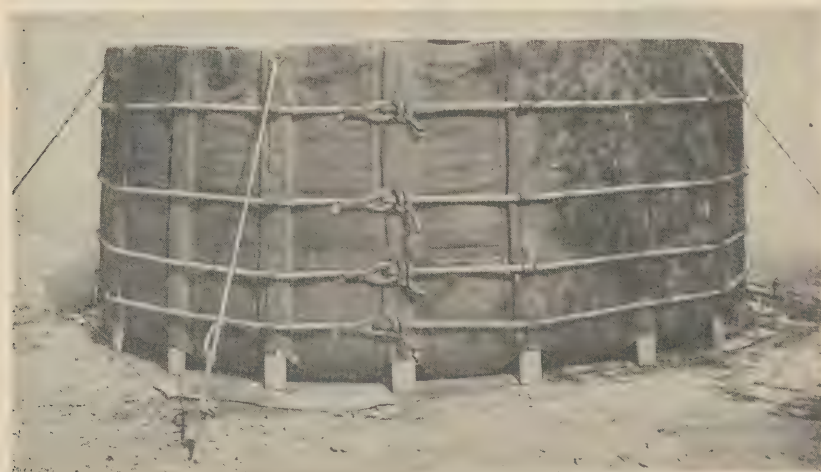


Figure 81. Canvas 3,000-gallon tank with inclosed staves.

(b) The Vinylite-coated 3,000 gallon tank weighs 300 pounds. Staves are held in place by a toe strap at the base of the tank, and by a pocket of glass fabric which extends to the top of the tank. It has two 2-inch outlets opposite each other and it is furnished with 16 staves and cover. No support ropes are used.

(c) The 500-gallon glass-fabric tank is lined with GR-S synthetic rubber and weighs about 60 pounds, complete with eight staves and a cover. Each stave is held against the tank by a toe strap at the base of the tank and two glass-fabric patches on the sides of the tank. There is one 1½-inch outlet near the bottom of the tank.

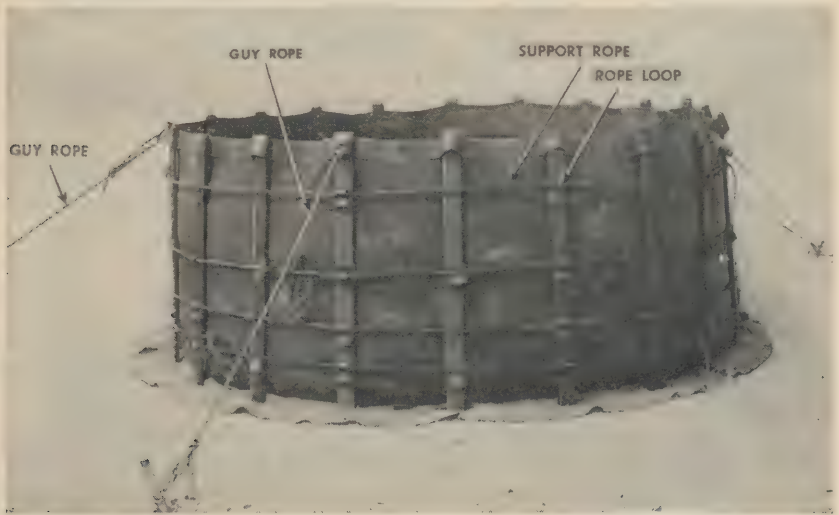


Figure 82. GR-S rubber-coated, glass-fabric 3,000-gallon tank.

c. **USE OF FABRIC TANKS.** Fabric tanks are used as storage reservoirs for water suitable for human consumption and as coagulation and sedimentation basins. They are easy to erect and take down, and can be carried in standard vehicles.

(1) Canvas tanks mounted on level wooden platforms will last about 2 months. Installed directly on the ground, they rot in 4 to 6 weeks. Unless metal tanks are not available, canvas tanks should not be used if they are to remain in one place for more than 6 weeks.

(2) Glass-fabric tanks are designed to resist mold and rot. Length of service depends on the care taken to prevent creasing of the glass fabric by sharp folds.

d. **INSTALLATION AND MAINTENANCE HINTS.** (1) All tanks must be installed level and on ground free of rocks or tree roots which might puncture the tank. Canvas tanks should be placed on a

wood platform or canvas-tank cover, if wood is not available. Glass-fabric tanks can be placed directly on the ground without danger of rot.

(2) When a 3,000-gallon canvas or GR-S rubber-lined tank is filled with water, the following procedure should be used to adjust the rope supports:

(a) After tank is erected and ready to be filled, tighten all ropes so sides of tank overlap rope. Tie ropes with two half hitches as shown in figure 83.

(b) Fill tank with water. Let out ropes while tank is filling so sides of tank are not cut by ropes, but ropes *support* the water in the tank. Filled tank should have right-cylindrical shape shown in figure 82.

Note. If ropes are too loose while tank is filling, the seams of the tanks are strained, shortening the life of the tank. It is impossible to take up ropes on a filled tank.

(c) After first adjustment, take up tank ropes daily to keep tank in proper shape. Adjustments must be made when tank is empty.

(3) In caring for canvas tanks—

(a) Do not dry tanks in direct sunlight.

(b) Do not repeatedly dry and refill tanks in service. When a dry tank is wetted the seams are strained, and permanent leaks often develop.

(c) To prepare a canvas tank for storage or shipment, thoroughly air-dry it in a shaded place. Treat it with a 1 percent copper sulfate solution, if available, to prevent mold growth, and bundle tank in its own cover. Tank bundle may be tied securely with wire or light rope.

(4) In caring for glass-fabric tanks—

(a) Do not fold Vinylite-impregnated or GR-S rubber-lined tanks. They should be rolled into a loose, cigar-shaped bundle. Glass fabric breaks if creased sharply.

(b) Do not walk on glass-fabric tanks or stack heavy objects on top of them.

(c) Cover metal outlets with rags before tanks are rolled.

110. Hose

a. DESCRIPTION. There are two general types of hose used in water supply:

(1) *Suction hose.* Suction hose is made of heavy rubber and fabric and is reinforced inside with metal to prevent collapsing. The ends of the hose are made of heavy brass, the female end having a collar coupling and a gasket recess.

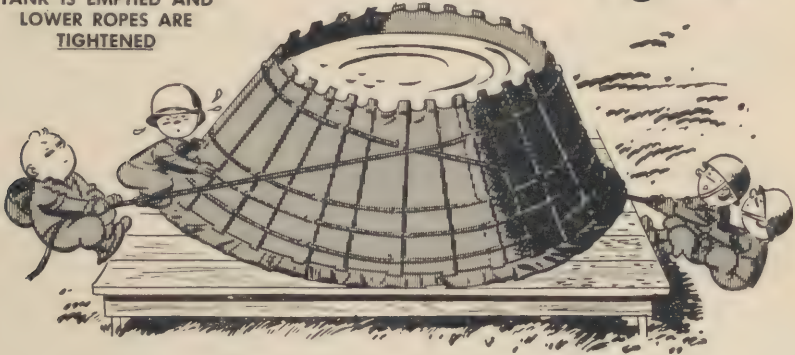
(1) THESE TANKS WILL SOON LEAK ...

Unless:

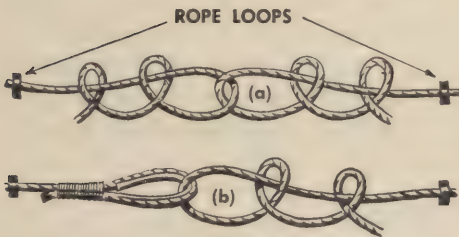
TANK IS TAKEN DOWN AND
PLATFORM IS LEVELED



TANK IS EMPTIED AND
LOWER ROPES ARE
TIGHTENED



HINTS



(2) JOIN TANK ROPES WITH TWO
HALF HITCHES ON END OF EACH
ROPE (a) OR TWO HALF HITCHES
CONNECTED TO THIMBLE (b).
LOCATE TIE MIDWAY BETWEEN
ROPE LOOPS TO ALLOW ROOM
FOR ADJUSTMENT

(3) PUT PATCHES INSIDE OF
TANK AND SEW AS SHOWN.
COAT PATCH WITH CANVAS
CEMENT BEFORE SEWING ON
IF CEMENT IS AVAILABLE



Figure 83. Hints for care of 3,000-gallon fabric tanks.

(2) *Discharge hose.* Discharge hose issued in engineer sets is canvas with a rubber lining. It is flexible and can be rolled into a tight coil. This hose has brass fittings at both ends, the female end having a collar coupling and a gasket recess.

b. **USE AND MAINTENANCE OF HOSE.** (1) Suction hose is used in all pump suction lines. It can also be used as discharge hose. Never put the hose under tension because the brass fittings at each end may be pulled loose.

(2) Canvas discharge hose is used only on a pump discharge line or other water line where there is water pressure. Because this hose is light it kinks readily and may stop the flow of water from a 55-gpm pump. The canvas wears rapidly if the hose is continuously dragged across the ground. It is impractical to connect two of these hoses together, because of kinking and the consequent head loss.

Section XI. OPERATION OF WATER SUPPLY EQUIPMENT IN FREEZING WEATHER

111. General

a. At temperatures below freezing, all parts of water supply equipment which conduct water freeze and hinder or prevent operation. Small-diameter metal and rubber tubes usually freeze first because of the thin stream of water flowing through them. Valves freeze quickly because a film of water remains on stems and seats. Sand filters freeze during operation because water flows through them too slowly, and because of the large exposed surface areas. Hose, pumps, and tanks generally freeze last.

b. Pump impellers freeze to the pump housing when the pump is stopped, even though the pump housing has been drained, because water is retained between the pump impeller and pump housing.

112. Methods of Preventing Freezing

a. General procedures to be followed in operating the mobile purification unit during freezing weather are:

(1) *Close body of unit as tightly as possible.* On the closed-body-type, the doors and windows are shut to close the body. Windows at the open end of the body on the older open-body-type unit must be boarded or covered with extra canvas.

(2) *Check exhaust muffler on motor for tight connections. Do not start pump unless muffler is leakproof.* Prime pump with water, but do not put suction hose in source. Start engine.

(3) Water may be pumped through the mobile unit when temperature inside the body is above 32° F.

(4) At temperatures less than 40° F., the chlorinator may not operate properly because the chlorine gas may liquefy at the center of the compensator or at the chlorine-diffuser assembly. To gasify liquid chlorine, warm cap in center of compensator assembly (fig. 36(1)) with the hand or with a candle. Close check must be made on chlorine residual during cold-weather operation. If proper residual cannot be maintained, batch chlorination of tanks with calcium hypochlorite is necessary. Chlorinator will not operate 20° F. Do not stimulate the flow of chlorine gas in cold weather by artificially warming the chlorine cylinder. The chlorinator should be at a warm, even temperature before operation is attempted.

(5) If temperature inside cab is below freezing during operation, all valves should be opened slightly to prevent freezing.

(6) At end of day's operation drain pump, chemical pots, filter, and pipe and hose lines.

b. General procedures to be followed in operating the portable sand-filter and the diatomite units during freezing weather are:

(1) Construct a windbreak over the filter and pump and engine assemblies. Use a fabric tank cover or shelter halves. Place filter nearest to windbreak, with exhaust of pump engine directed against it.

(2) Crack all valves so a small stream of water seeps from them.

(3) At temperatures below 20° F., filter and pumping assemblies should be placed inside a pyramidal tent, wooden hut, Nissen hut, or other roofed shelter. A stove similar to tent stove M1941 is needed. Vent engine exhaust to outside. In arranging unit inside tent, place filter closest to fire.

c. Special measures which may be useful in operating mobile or portable equipment at temperatures below 0° F. are as follows:

(1) Install heater inside mobile unit body. No standard heater is issued for the mobile unit, so the Evanair heater assembly installed on engineer shop trucks or a hot-air heater similar to the Herman-Nelson heater used by the air forces should be used. Any heater installed must be properly vented.

(2) Hypochlorite solution in the portable sand-filter unit is prevented from freezing by replacing the rubber-solution reservoir with a 14-quart bucket, and heating the bucket with a one-burner gasoline stove.

(3) Preheat water before purification. The preheater should be located as close to the suction strainer as possible. A satisfactory issue preheater is the heater from the standard eight-man shower

unit. Preheaters can be made of any pipe available. A satisfactory one can be made from several short lengths of 1- to 2-inch pipe bent around the edges of a shallow pit 4 feet square. A wood or coal fire is built in the center of the pit. Preheater must warm water enough so filtered water leaving the units is 2° or 3° above freezing.

CHAPTER 5

DISTILLATION EQUIPMENT

Section I. GENERAL

113. Purpose

a. Distillation equipment is used to produce fresh drinking water from brackish water, sea water, or other waters containing excessive amounts of dissolved solids. In emergencies, it can be used to produce drinking water from contaminated or polluted fresh-water sources. Distillation equipment can also be used to produce water low in total solids for other than drinking purposes.

b. The distillate produced is almost pure since all dissolved solids remain behind in the equipment and gases are vented to the air. Nevertheless, all distillate must be disinfected before being consumed by troops. (See par. 41.) This is required by Army standards to prevent contamination by handling.

114. Types of Distillation Equipment

a. TYPES OF EQUIPMENT. Distillation equipment is classified as oil-fired or thermocompression-type, depending on the source of heat for evaporating the water.

(1) *Oil-fired equipment.* Heat for oil-fired equipment is provided by burning liquid fuels in a steam generator. Such equipment can be either single-, double-, or triple-effect, according to the number of evaporators on the unit. Single-effect units produce about 12 pounds of distilled water per pound of fuel burned, double-effect units about 24 pounds, and triple-effect units about 36 pounds. Each unit also burns approximately 1 gallon of gasoline per hour.

(2) *Thermocompression-type equipment.* In thermocompression distillation equipment, the heat is produced by the cooling and exhaust systems of a gasoline or Diesel power unit and by the mechanical compression of steam. Such equipment produces 100 to 200 pounds of distillate per pound of fuel used.

b. PHYSICAL AND OPERATING DATA. All Army distillation equipment is skid- or trailer-mounted to facilitate handling and

Table XV. Physical and operating data for Army distillation units

| Type | Distillate capacity* | | Economy Pounds distilled per pound fuel | Fuel required | | Raw water required | Mounting | Weight pound | Dimensions | | |
|--|----------------------|-------|---|--------------------|---------|-----------------------|--------------------|-----------------|-----------------|----------------|----------------|
| | gph | gpd | | Type | gph | | | | Length | Width | Height |
| Oil-fired, double-effect | 100 | 2,000 | 24 | Gasoline Diesel | 1 5 | 600 | Trailer | 9,000 | 17'-9" | 7'-4" | 5'-10" |
| Oil-fired, double-effect | 250 | 5,000 | 24 | Gasoline Diesel | 1 12 | 1,500 | Skid | 11,100 | 16'-9" | 6'-6" | 7'-6" |
| Oil-fired, triple-effect | 125 | 2,500 | 36 | Gasoline Diesel | 1 4 | 425 | Skid | 6,800 | 11'-6" | 4'-0" | 5'-8" |
| Thermo-compression | 60 | 1,200 | 100 | Gasoline | 1 | 130 | Skid or Trailer | 4,300 4,700 | 7'-8" 12'-7" | 4'-6" 7'-0" | 5'-6" 6'-2" |
| Thermo-compression (Badger) | 150 | 3,000 | 150 | Gasoline | 1.5 | 325 | Skid | 7,500 | 9'-8" | 4'-6" | 6'-3" |
| Thermo-compression (Cleaver-Brooks) | 150 | 3,000 | 150 | Gasoline | 1.5 | 325 | Skid | 7,500 | 11'-2" | 4'-2" | 5'-6" |
| Thermo-compression | 300 | 6,000 | 200 | Diesel | 2.0 | 600 | Skid | 13,600 | 9'-1" | 5'-7" | 6'-4" |

* The distillate capacity in gpd is calculated on the basis of the Corps of Engineers 20-hour day.

field installation, and is assembled as a complete unit with power unit, pumping equipment, and necessary piping and controls. Table XV gives physical and operating data for Army distillation units.

115. Basic Principles of Distillation

a. GENERAL. Distillation is the process of changing water into water vapor, separating the water vapor or steam from the water, and changing this steam back into water. The dissolved solids do not vaporize but remain behind in the raw water. This cycle requires heating the raw water and removing that heat from the steam. Changing boiling water to steam (vaporization) requires a large amount of heat which is not evidenced as a rise in temperature. This is known as the latent heat of vaporization. To change 1 pound of water to 1 pound of steam at 212° F., the latent heat of vaporization required is 970 British thermal units (BTU). A BTU is the quantity of heat required to raise the temperature of 1 pound of water 1° F. This latent heat remains in the steam, which will not condense until the latent heat is removed. The process of removing the latent heat and changing the steam to water is known as "condensation." A distillation unit in its simplest form, then, consists of a source of heat to evaporate the water, an evaporator in which the water is converted to steam, and a condenser in which the steam is reconverted to water. (See fig. 84.) Condensation is accomplished by running cooling water through the condenser. Generally, a portion of the cooling water

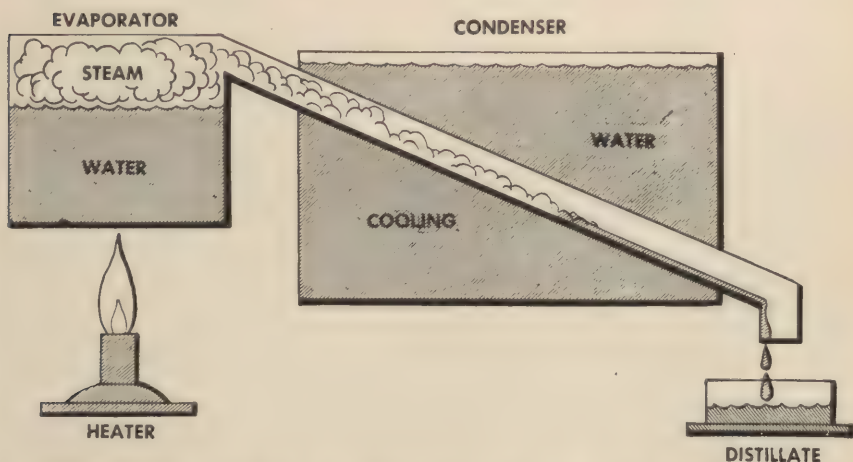


Figure 84. Distillation unit in its simplest form. Heat flows through the bottom of the evaporator, enters the water, and changes the water to steam. The steam is condensed in the condenser, its latent heat of vaporization being transferred to the water surrounding the tubes.

which has picked up heat in passing through the condenser is used as feed water for the evaporator.

b. OIL-FIRED DISTILLATION EQUIPMENT (ARMY). Army oil-fired distillation equipment is the multiple-effect type in which the latent heat of vaporization produced in one evaporator is used to generate steam in another evaporator. (See fig. 85.) In double-effect distillation units, the latent heat of vaporization of the steam produced in the first evaporator is used to produce steam in a second evaporator. In triple-effect units, the latent heat of the steam generated in a second-effect evaporator is used to form steam in a third evaporator. The three evaporators are known as the first effect, second effect, and third effect. When steam is compressed or confined, its temperature increases proportionately to the increase in pressure. This fundamental fact is used in multiple-effect units.

(1) *Double-effect units.* In oil-fired double-effect units, an oil-

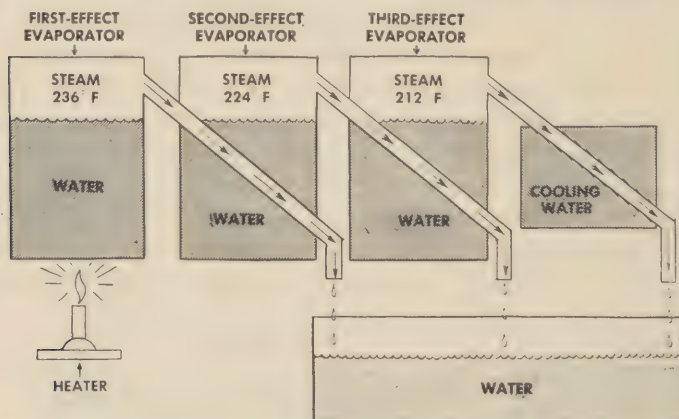


Figure 85. Multiple-effect distillation in its simplest form. Heat flows into the first-effect evaporator and changes some of the water to steam by furnishing the necessary latent heat of vaporization. The steam is confined, raising its pressure enough to increase the temperature to 236° F. This steam from the first effect then flows through a coil immersed in the water of the second effect. There its latent heat is transferred to the water, causing it to condense as distillate and changing an equal amount of second-effect water into steam. This steam is not confined as much as that from the first-effect; therefore, its pressure and temperature are less. This difference in temperature is essential for the transfer of the latent heat. Steam from the second effect at 224° F. flows through a coil immersed in the water of the third-effect evaporator, where its latent heat is again transferred, causing all the steam to condense as distillate and changing an equal amount of the third-effect water into steam. Steam from the third-effect is not confined; therefore, its temperature is 212° F. It flows through a coil immersed in cool water, where it transfers its latent heat to the water and condenses into distillate. In actual units the cooling water from the condenser is used as feed water for the first effect.

burner and fire-tube assembly supply enough heat to vaporize some of the water in the first effect. The steam generated is confined, thus building up pressure in the evaporator and raising the steam temperature. This steam is piped to coils in the second effect where its latent heat is transferred to the water surrounding the coils, condensing the steam from the first effect and producing steam in the second effect at a lower pressure and temperature than that of the first-effect. This transfer of latent heat is possible because of the difference in temperature between the steam from the first effect and the steam produced in the second effect. Both steam and condensate formed in the second effect are passed through a water-cooled condenser and emerge as distillate. Cooling water which has absorbed heat in the condenser is used as feed water for the first effect. To maintain a constant water level in both effects and to prevent salt concentrations reaching the point where salt would precipitate in large quantities, feed water flows through the first effect to the second effect, from which a portion is discharged to waste in amounts equal to the distillate produced. This waste water is known as "blowdown."

(2) *Triple-effect units.* In triple-effect units, transfer of latent heat among the three effects is possible because pressure and temperature are higher in the first effect than in the second effect and higher in the second effect than in the third effect. As in double-effect units, feed water flows from the condenser through each evaporator and a portion is continually wasted as blowdown. The feed water is heated to operating temperatures by steam vented from the first effect. In triple-effect units maximum economy is obtained by heating the raw water with heat recovered from the distillate.

c. THERMOCOMPRESSION DISTILLATION EQUIPMENT. (1) In thermocompression distillation equipment as in oil-fired equipment, the latent heat of vaporization of steam produced is used to produce additional steam. Steam generated in the evaporator is compressed, raising its pressure and temperature. The compressed steam passes to the condenser section of the evaporator, where it condenses, giving up its latent heat and causing more steam to form in the evaporator. This steam is compressed in turn, and the cycle repeats. This use of a combination evaporator-condenser with a steam compressor creates a closed heat cycle permitting the continued re-use of the latent heat of vaporization. (See fig. 86.)

(2) The compressor is driven by a gasoline or Diesel water-cooled engine, and heat from the engine is used to replace heat lost by radiation, mechanical inefficiencies, noncondensable gases vented to atmosphere, and blowdown. To obtain maximum economy, evaporator feed water is run through heat exchangers which re-

cover heat from the distillate, blowdown, noncondensable gases, and the engine.

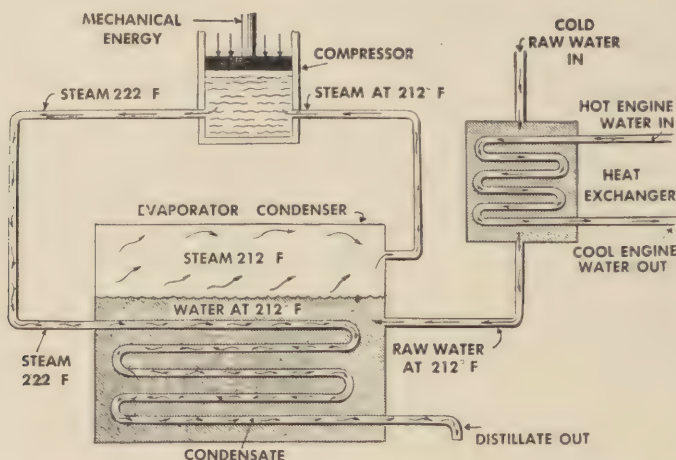


Figure 86. Diagram of thermocompression unit in its simplest form. Cold raw water flows through a heat exchanger where it is heated almost to boiling by hot water from the gasoline engine that drives the compressor. The hot raw water flows into the evaporator-condenser, where it is changed to steam by the steam condensing in the tubes. This involves the transfer of latent heat. (See par. 115a for principles.) The steam in the evaporator flows to the compressor where it is compressed and its temperature raised (from 212° F. to 222° F. in the diagram). The compressed steam flows back through the coils in the evaporator-condenser where it transfers its latent heat through the walls of the coil into the water in the evaporator section. This transfer of latent heat causes the steam to condense in the coils and changes the water in the evaporator into steam. This cycle will continue as long as the compressor runs.

116. Characteristics of Distillation Equipment

a. OIL-FIRED DISTILLATION EQUIPMENT. The operating efficiency and economy of oil-fired distillation equipment are determined by the quantities of heat and raw water supplied, by the quantity of blowdown, and by the various units' individual characteristics.

(1) *Quantity of heat.* The quantity of heat supplied to the unit varies with the amount of fuel burned, the kind of fuel burned, and the efficiency of the burner.

(a) *Amount of fuel burned.* With fuel pressure at 100 pounds, the 2,000-gpd double-effect unit burns 5 gallons of fuel an hour; the 2,500-gpd triple-effect unit, 4 gallons; and the 5,000-gpd double-effect unit, a total of 12 gallons, 4 per hour in each of three nozzles. Units must burn these quantities to produce at rated capacity. If more fuel is burned, too much heat is generated and salt carries over in the distillate (priming). If too little fuel is used, capacity falls off. The accuracy of the nozzle and the fuel pressure govern the quantity of fuel burned. The accuracy of nozzles is fixed in

design and must be determined by test; fuel pressure is adjustable.

1. If unit output is below rated capacity and all operating instructions have been followed, always check the quantity of fuel being burned. If burning less fuel than specified, check and adjust fuel pressure first. If test again proves fuel rate low, clean nozzle. If pressure is correct and nozzle clean and quantity of fuel being burned remains low, rate can be increased slightly by raising the fuel pressure. Fuel pressure can safely be raised to 140 pounds to obtain a proper fuel rate. If this fails to supply enough fuel, replace nozzle. Test curves showing effect of pressure on the flow through a nozzle are illustrated in figure 87.
2. If unit primes, allowing salt to carry over into distillate, and all other operation is normal, it may be that too much fuel is being burned. If so, check for a worn nozzle or an increase in fuel pressure. The fuel rate can be adjusted by lowering the fuel pressure. The lower limit recommended for atomization and combustion is 70 pounds. Figure 88 shows relationship of distillate to fuel oil pressure.

(b) Kind of fuel.

1. The fuel burners are designed to burn fuel-oil grades Nos. 1, 2, or 3, or Diesel fuel. Kerosene or gasoline may be substituted in an emergency.

Caution: If kerosene or gasoline is used as fuel, add one quart of light lubricating oil to each five gallons of fuel to lubricate the fuel pump. If when using gasoline, the burner fails to ignite immediately on opening fuel-supply valve or goes out during operation, completely clear gases from stack before relighting.

2. Different grades and kinds of liquid fuels generate different quantities of heat, the heat content varying with the fuel's specific gravity. This means that the quantity of fuel required to maintain the rated distillate output, established with No. 2 fuel, varies with the fuel used. Differences in the heat content of various fuels are shown by the following table. The correct amount is obtained by varying the fuel pressure.

| Fuel | BTU per pound | Pound per gal. | BTU per gal. |
|----------|---------------|----------------|--------------|
| Fuel oil | 18,650 | 8.3 | 155,000 |
| | 19,850 | 6.9 | 136,000 |
| Gasoline | 20,494 | 6.3 | 129,300 |
| | 20,874 | 6.0 | 125,000 |
| Kerosene | 19,924 | 6.8 | 136,000 |

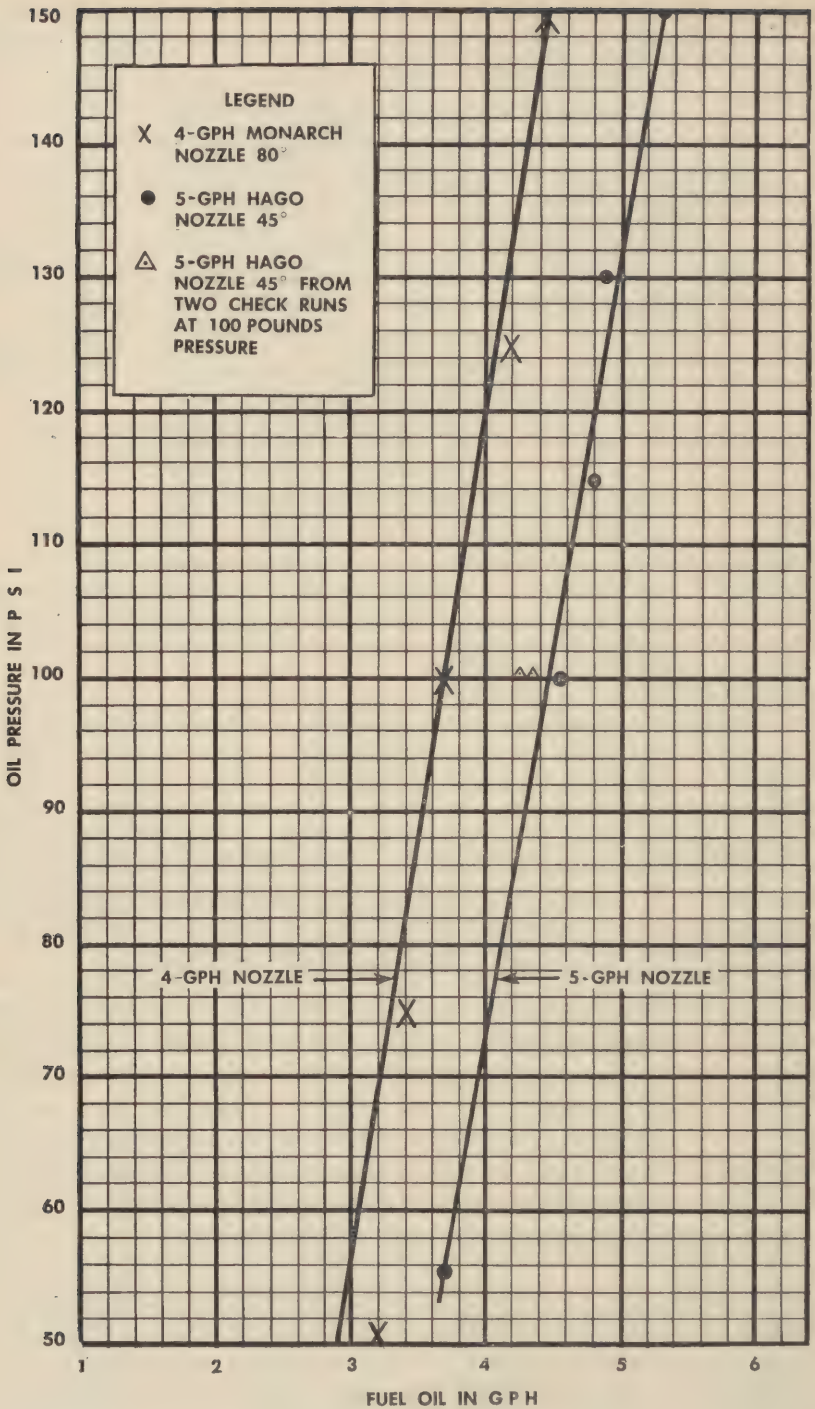
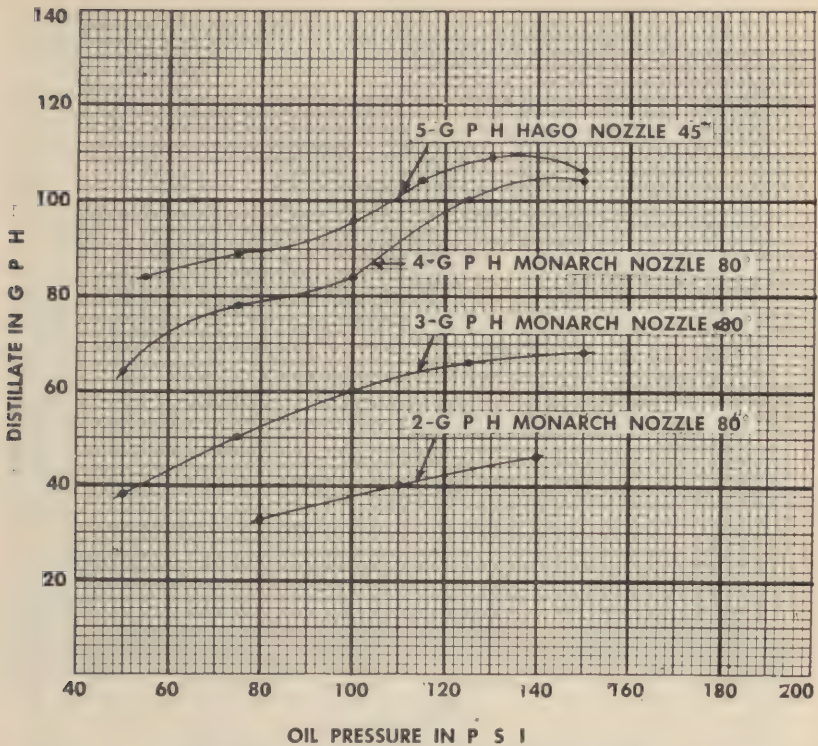


Figure 87. Test curves of effect of pressure on flow through a nozzle.

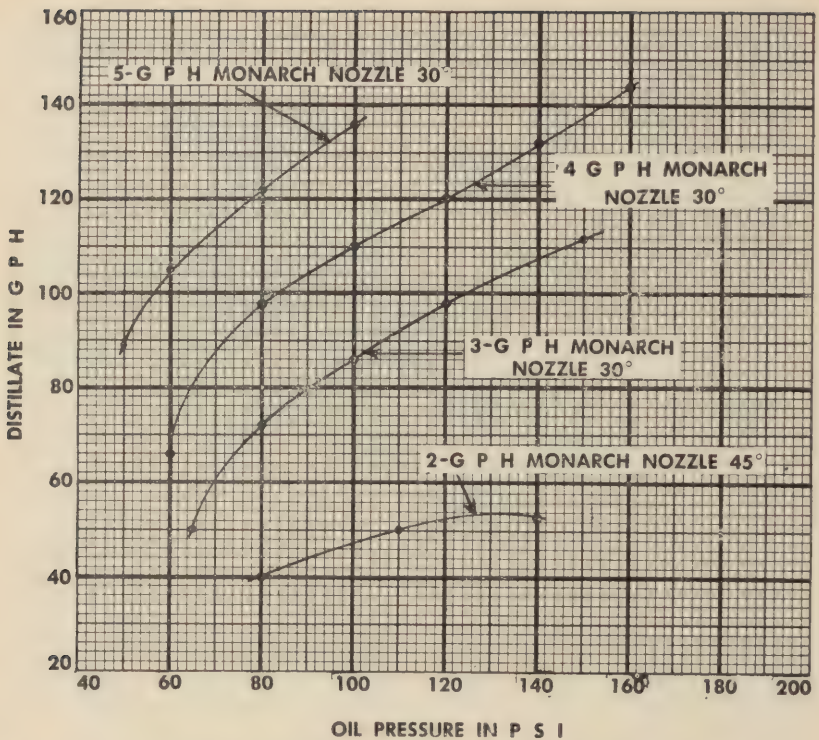


① 2,000-gpd double-effect distillation unit.

Figure 88. Test curves of effect of pressure on distillate output.

(c) *Efficiency of burner.* Burner efficiency is controlled by the quantity of air used for combustion. If too little air is used, combustion is incomplete and carbon is deposited in the burner and fire tubes; if too much air is used, fuel is wasted in heating air and heat losses are high. To obtain rated output and maximum economy, therefore, operating instructions direct that the damper at the blower air intake be adjusted so smoke just ceases to emit from the stack.

(2) *Quantity of raw water.* In oil-fired distillation equipment, raw water is used first as condenser cooling water and then as evaporator feed water. To produce distillate at the rated capacity and with maximum economy, raw water must be fed to the first-effect evaporator at the highest possible temperature. This is done by supplying only enough raw water to the condenser for complete condensation. The supply of raw water is correct for double-effect units when the temperature of first-effect feed water is 200° F. It is correct for triple-effect units when the raw water discharged from the condenser is 200° F. Supply can be adjusted by watching the condenser air-discharge vent. The raw-water supply



(2) 2,500-gpd triple-effect distillation unit.

Figure 88. Test curves of effect of pressure on distillate output (Contd.).

is properly adjusted when there is an occasional discharge of steam from this vent. No discharge indicates more raw water than necessary for condensation, and a steady discharge indicates less raw water than necessary.

(3) *Blowdown*. It is essential to maintain a blowdown rate equal to distillate production. Too little blowdown results in high concentration and precipitation of soluble salts (NaCl) in the evaporators, retarding heat transfer and necessitating cleaning. Too much blowdown wastes heat unnecessarily.

(4) *Individual characteristics*. Tests and actual operations have proved that each of the oil-fired units has certain individual characteristics. Outstanding characteristics are noted below as a guide to best operation.

(a) *2,000-gpd unit*. In the 2,000-gpd unit, the quantity of heat supplied to the second effect must be accurately controlled to prevent priming. Assuming normal operating conditions, this is done by adjusting the condensate regulator valves (control valves at condensate discharges of evaporator heat exchangers) to maintain the lowest possible constant steam pressure in the first effect. Op-

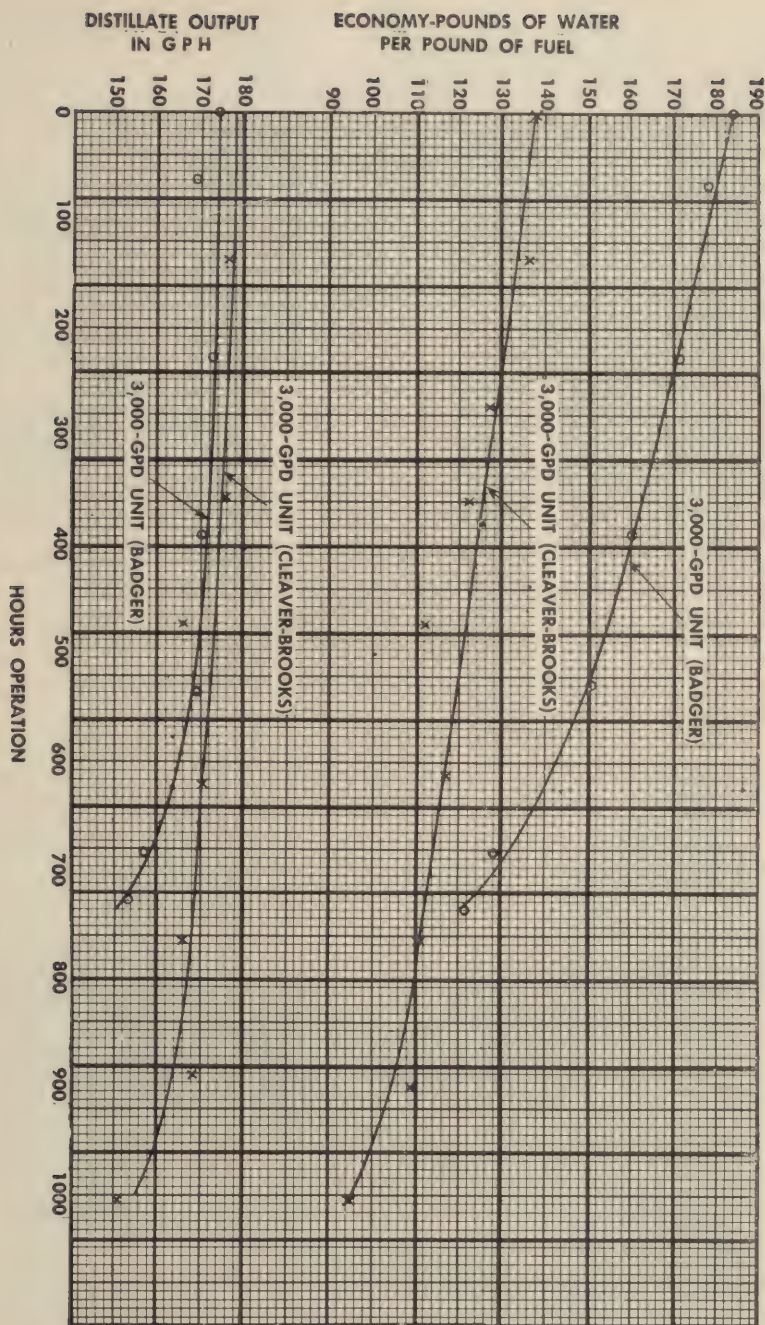


Figure 89. Test-data curves on two pilot-model 3,000-gpd thermocompression distillation units showing distillate output and economy.

erating conditions are normal when proper amount of heat is supplied to first effect, first-effect feed temperature is 200° F., and quantity of blowdown is 100 gph.

(b) *5,000-gpd unit.* In 5,000-gpd units, it is important to control the water level in the first effect accurately. If the water level is allowed to rise above 1 inch in the gauge glass, raw water will be carried over from the first effect. It is also essential that the water level never go below the gauge-glass level.

(c) *2,500-gpd unit.* In 2,500-gpd units, the first effect is subject to priming. This can happen with all other conditions normal, if an attempt is made to increase production by supplying too much heat through the burner, or by operating with a greatly reduced first-effect feed and blowdown rate.

b. THERMOCOMPRESSION DISTILLATION EQUIPMENT. (1) *General.* In thermocompression distillation equipment, production of distillate at rated capacity and maximum economy depends primarily on the compressor's ability to transfer and compress vapor.

(2) *Distillate capacity.* Because all distillate produced must pass through the compressor as vapor, the unit distillate capacity and compressor volumetric capacity are identical. The compressors are positive-displacement type, capacity varying directly with the speed. Basically, then, with a constant compressor speed, a constant quantity of distillate is produced. Output decreases, however, when scale forms on evaporator heat-exchanger elements, causing higher pressures and less efficient compressor operation.

(3) *Economy.* As economy varies directly with the power input to the compressor, engine performance is of major importance. When scale forms in the evaporator, resistance to heat transfer increases. This resistance prevents complete condensation of the steam, thereby building up pressure in the condenser section of the evaporator. As the compressor must work against this pressure, the differential between suction and discharge pressures increases. This increased pressure differential requires more power and reduces the efficiency of the compressor. Typical thermocompression-unit performance is illustrated in figure 89, showing distillate output and economy plotted against time.

Section II. DOUBLE-EFFECT OIL-FIRED DISTILLATION EQUIPMENT

117. General

The 2,000-gpd (fig. 90) and 5,000-gpd (fig. 91) double-effect oil-fired distillation units are similar in design. A number of component parts are identical, and the remaining parts differ only in size required to produce the rated capacities. The following discussion of the function of parts refers to both units.

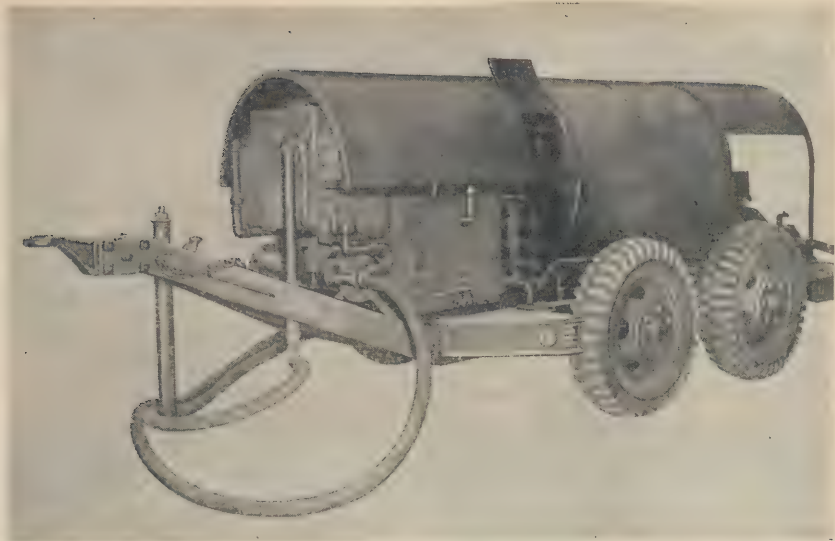


Figure 90. Trailer-mounted 2,000-gpd double-effect oil-fired distillation unit. This unit weighs 9,000 pounds, is 17 feet 9 inches long, 7 feet 4 inches wide, and 5 feet 10 inches high.

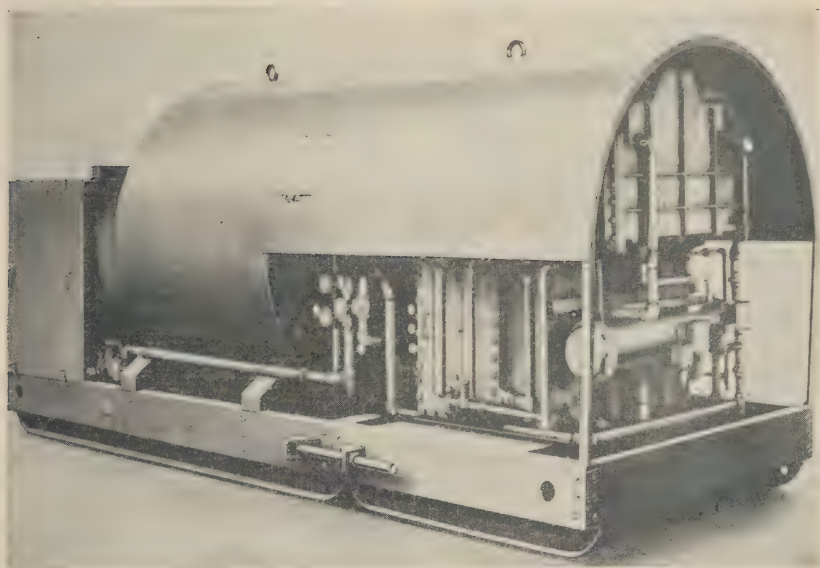


Figure 91. Skid-mounted 5,000-gpd double-effect oil-fired distillation unit. This unit weighs 11,100 pounds, is 16 feet 9 inches long, 6 feet 6 inches wide, and 7 feet 6 inches high.

118. Function of Parts

Both double-effect distillation units consist of a fuel-burner assembly, a first-effect evaporator, a second-effect evaporator, a condenser, a cooler, a deaerator, an engine, a raw-water pump, and an evaporator-feed pump. Zinc plates provided in the first-effect evaporator, the second-effect evaporator, and the cooler prevent corrosion of the steel. The 2,000-gpd unit is mounted on a tandem-axle four-wheel trailer, and the 5,000-gpd on a sectional steel skid. Both units are completely inclosed for protection from the weather. Figures 92 and 93 show cutaway views of the 2,000- and 5,000-gpd double-effect oil-fired distillation units. A flow diagram is shown in figure 94.

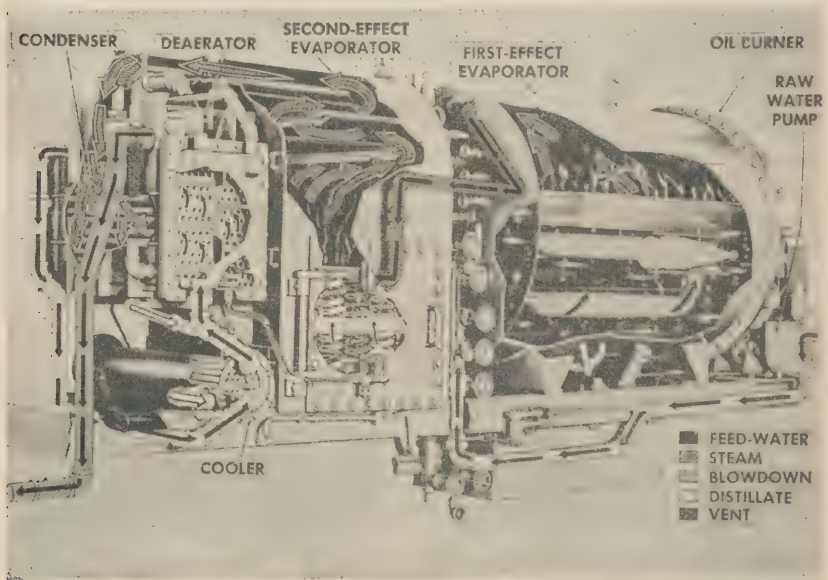


Figure 92. Cutaway view of 2,000-gpd double-effect distillation unit.

a. **FUEL-BURNER ASSEMBLY.** The fuel-burner assembly provides heat to evaporate the water in the first-effect evaporator. It consists of an internal gear-type fuel pump, two disk-type strainers, a blower, a pressure regulator, and an atomizing burner. The 2,000-gpd unit has a single-nozzle burner and the 5,000-gpd a three-nozzle burner.

b. **FIRST-EFFECT EVAPORATOR.** The first-effect evaporator is an oil-fired eight-pass fire-tube steam generator. The burner assembly heats the water surrounding the fire tubes and generates water vapor (steam). The steam flows through pipes to the coils of the second-effect evaporator. Enough raw water is pumped from the

deaerator to the first-effect evaporator to supply first-effect steam, second-effect feed water, and blowdown.

c. **SECOND-EFFECT EVAPORATOR.** The second-effect evaporator is a rectangular steel shell with two banks of coils. Water at the boiling point from the first effect flows into the shell and surrounds the coils. Steam from the first effect flows into the second-effect coils, transfers its latent heat of vaporization to the second-effect water, producing steam, and is itself condensed as distillate. Distillate from the coils and the steam generated in this effect pass to the condenser. An automatic blowdown maintains a constant water level in the second effect.

d. **CONDENSER.** The condenser is a horizontal multipass tubular heat exchanger. Steam from the second effect passes around the tubes and is condensed. Water flowing through the tubes is heated. Condensate from the second-effect coils also passes into the condenser.

e. **COOLER.** The cooler, a horizontal multipass tubular heat exchanger, is used to cool the distillate and to heat raw water. The hot distillate flows around the tubes of the cooler, heating the raw water within the tubes.

f. **DEAERATOR.** The deaerator is an open rectangular tank divided into three sections: evaporator feed-water flow section, evaporator feed-water reservoir section, and waste-water section. The deaerator is used to dissipate noncondensable gases dissolved in the evaporator-feed water to the atmosphere.

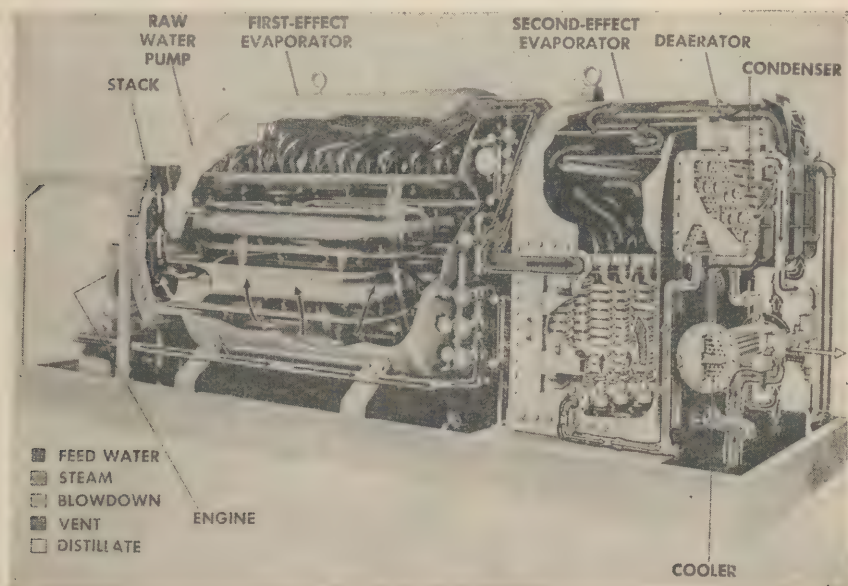


Figure 93. Cutaway view of 5,000-gpd double-effect distillation unit.

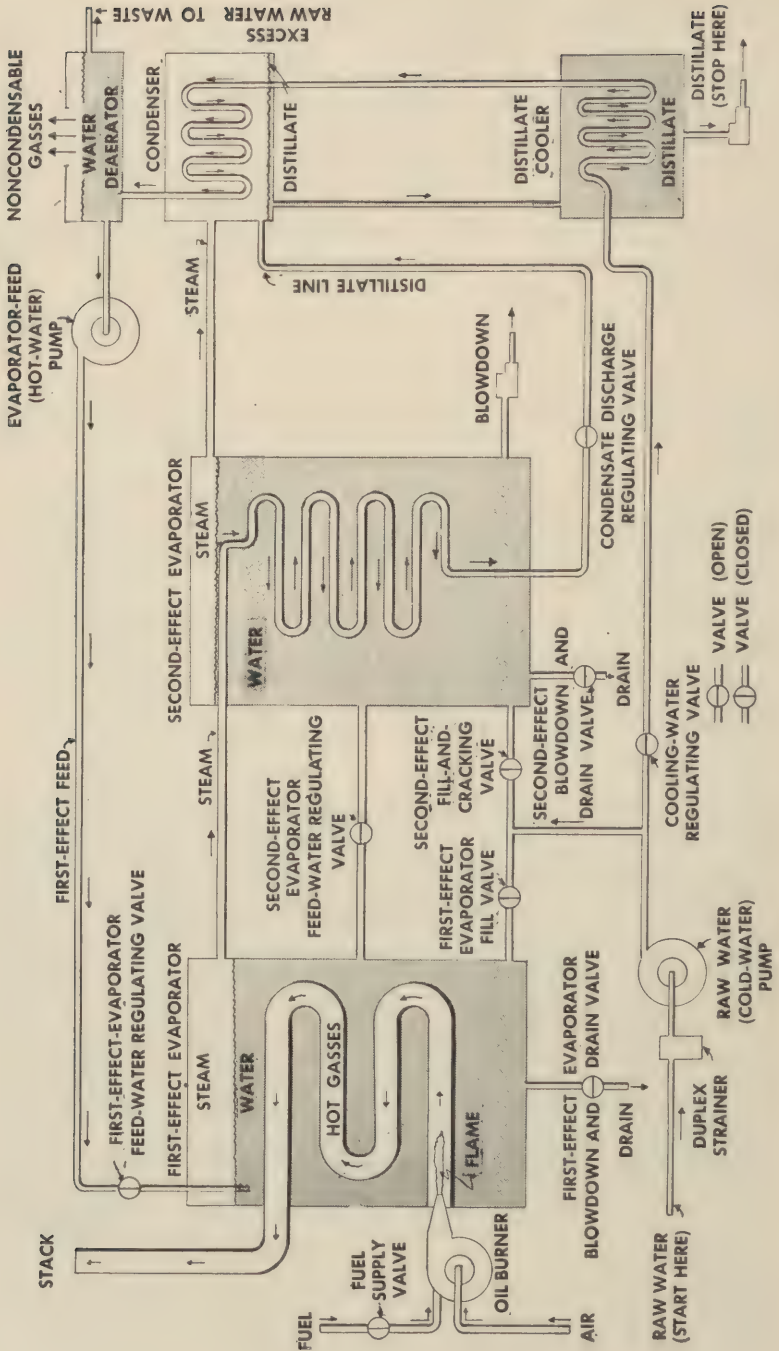


Figure 94. Flow diagram of the oil-fired double-effect distillation units. Raw water flows through the duplex strainer into the raw-water pump, through the cooling-water regulating valve, and into tubes of the distillate cooler where it is heated by the warm distillate. The warm raw water then flows through tubes in the condenser where it is further heated by condensing steam and hot distillate. The hot raw water flows through the deaerator and gives off noncondensable gases to the atmosphere. From the deaerator, part of the hot raw water flows into the first-effect evaporator-feed (hot-water) pump and into the first-effect evaporator. The excess raw water flows to waste from the deaerator. In the first-effect, some of the water is changed to steam and the remainder flows to the second-effect as feed water. The steam from the first-effect flows through coils in the second-effect where it is condensed. This condensate flows through condensate-discharge regulating valves to the condenser. The steam made in the second-effect flows to the condenser where it is condensed to distillate. It then flows to the distillate cooler and to storage. Hot raw water from the second-effect flows to waste as blowdown.

g. ENGINE. The engine is an air-cooled gasoline engine. It drives the raw-water (cold-water) pump, the evaporator-feed (hot-water) pump, the fuel pump, and the burner-assembly blower.

h. WATER PUMPS. The raw-water and the evaporator-feed pumps are all-bronze open-impeller centrifugal pumps.

119. Operation of 2,000-GPD Double-Effect Distillation Unit.

See TM 5-2060 for detailed operating instructions. Unit is operating correctly when—

a. Fuel consumption is 5 gph.

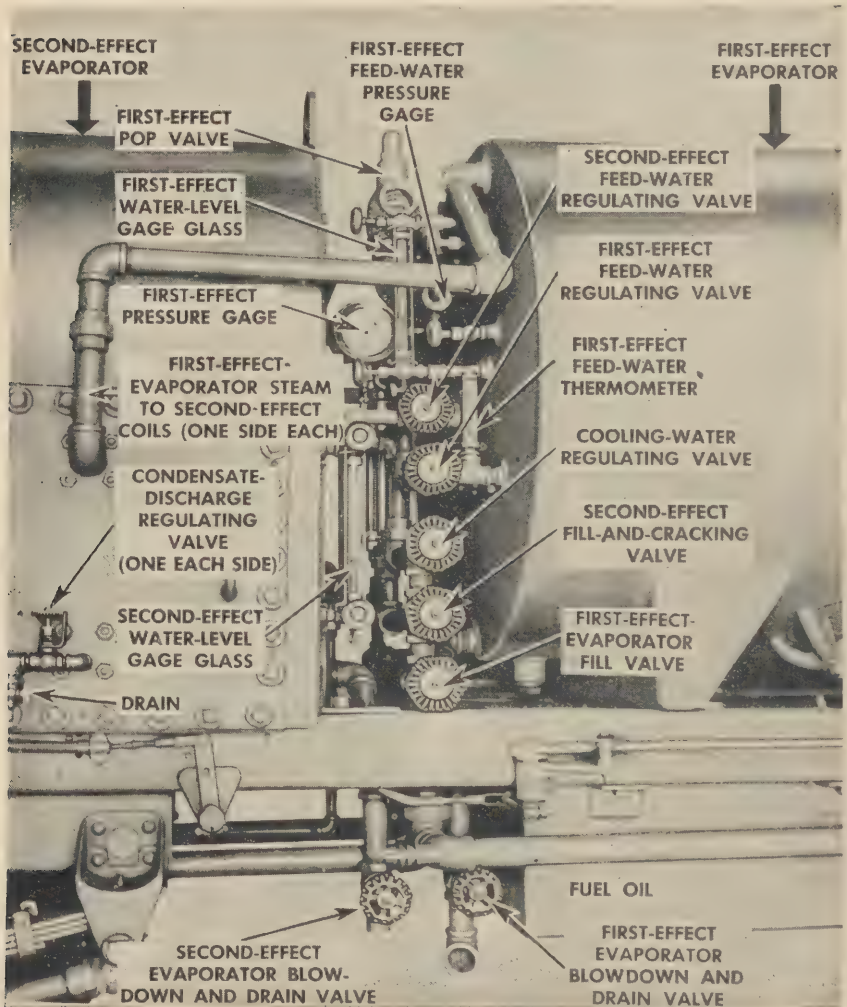


Figure 95. Water valve-control station of the 2,000-gpd double-effect distillation unit.

- b. Slight blue haze comes from stock.
- c. Engine runs at 1,750 rpm.
- d. Occasional wisp of steam comes from condenser vent.
- e. Distillate is clear and not salty.
- f. Distillate and blowdown flows are approximately equal.

120. Operation of 5,000-GPD Double-Effect Distillation Unit
See TM 5-2064 for detailed operating instructions.

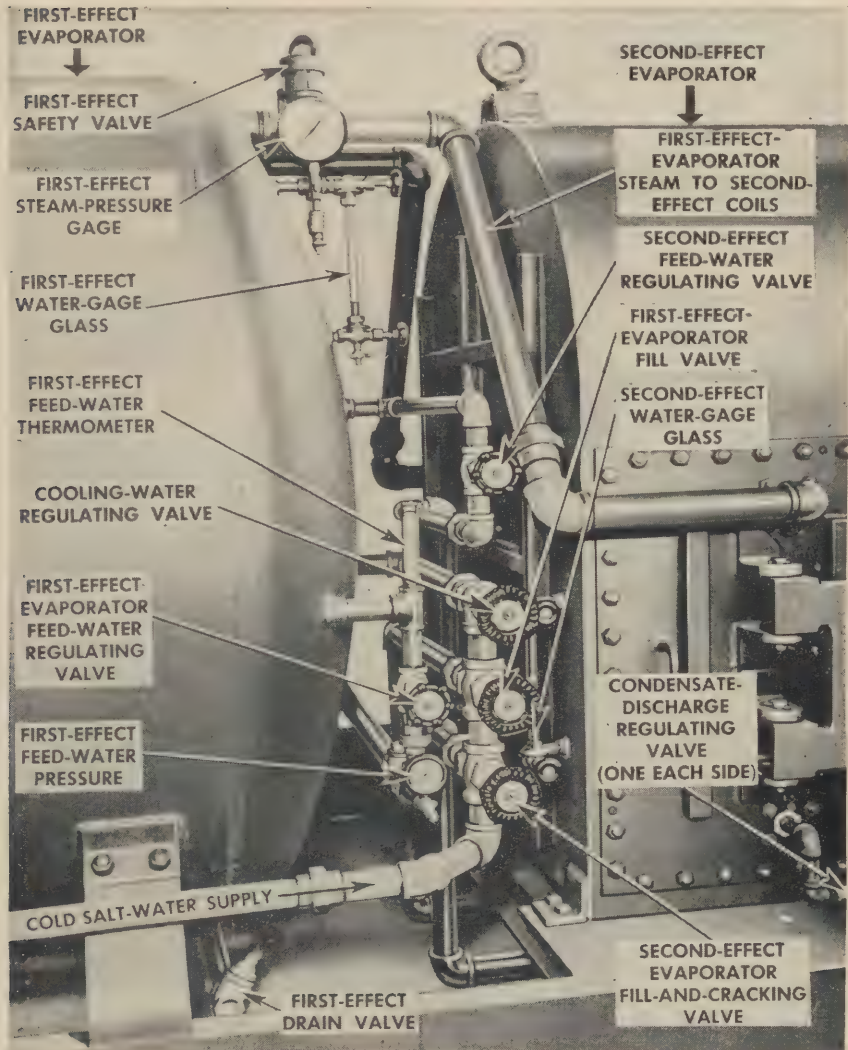


Figure 96. Water valve-control station for the 5,000-gpd double-effect distillation unit.

121. Shutdown

To shut down either unit, close oil-supply valve to burner but continue engine operation to circulate cool water until flow of distillate stops. Shut off engine. For temporary shutdown, close all operating valves. For prolonged shutdown, drain unit completely.

Section III. TRIPLE-EFFECT OIL-FIRED DISTILLATION UNIT

122. Function of Parts

The 2,500-gpd unit (fig. 97) consists of a fuel-burner assembly, a first-effect evaporator, a second-effect evaporator, a third-effect evaporator, a condenser, a cooler, a first-effect preheater, a deaerator, an engine, a raw-water pump, and an evaporator-feed pump. The unit is mounted on a completely inclosed skid frame. Zinc plates are provided in the first-, second-, and third-effect evaporators, the condenser, the cooler, and the preheater to prevent corrosion of the steel. A cutaway view showing flow is given in figure 98.

a. FUEL-BURNER ASSEMBLY. The fuel-burner assembly provides heat to evaporate water in the first-effect evaporator. It consists of an internal gear-type fuel pump, two disk-type oil strainers, a pres-

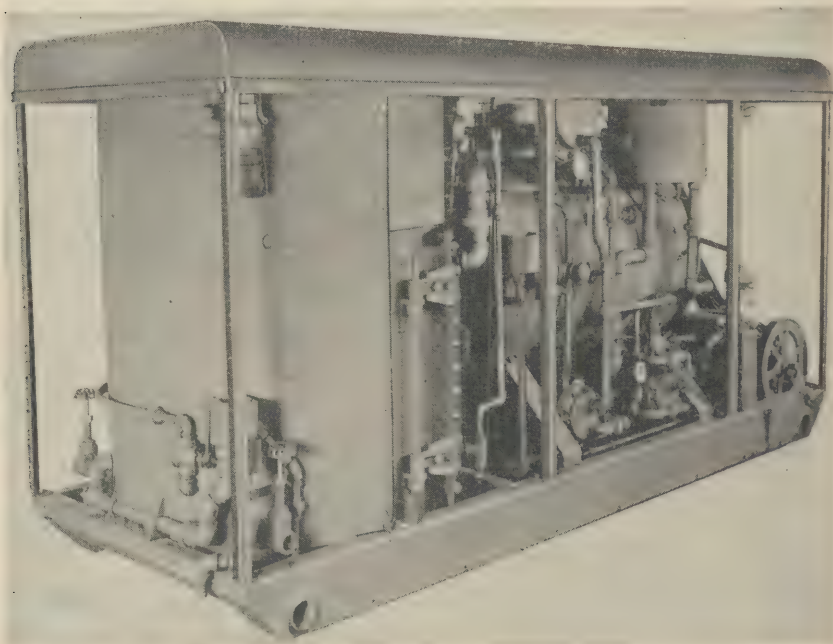


Figure 97. Skid-mounted 2,500-gpd triple-effect oil-fired distillation unit. This unit weighs 6,800 pounds, is 11 feet 6 inches long, 4 feet wide, and 5 feet 8 inches high.

sure regulator, a blower, an atomizing-type single-nozzle burner.

b. **FIRST-EFFECT EVAPORATOR.** The first-effect evaporator is an oil-fired six-pass fire-tube steam generator. The oil flame of the burner heats the water surrounding the fire tubes and generates steam which is piped to coils in the second effect. Blowdown is provided by using the water in the first-effect evaporator as second-effect-evaporator feed water.

c. **SECOND- AND THIRD-EFFECT EVAPORATORS.** The second- and third-effect evaporators are identical in design and are inclosed in a single cylindrical shell with the two effects separated by a double partition. The steam formed in the first effect is condensed and forms steam in the second effect. The steam formed in the second effect is condensed and forms steam in the third effect. Water continually blown down from the second effect provides water for the third effect. From the third effect, blowdown is discharged to waste.

d. **CONDENSER.** The condenser is a horizontal multipass tube-type heat exchanger. Steam from the third effect passes around the tubes, is condensed, and heats the water within the tubes. The

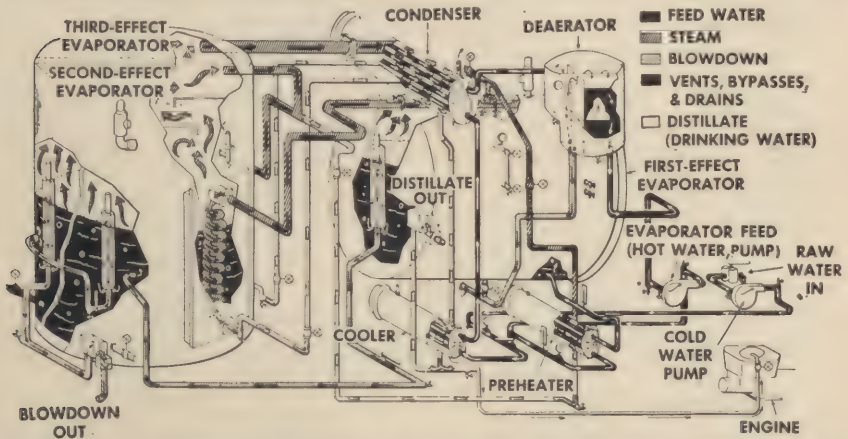


Figure 98. Cutaway view showing flow through 2,500-gpd triple-effect oil-fired distillation unit. Raw water enters at the strainer, is pumped to the cooler where it picks up heat from the distillate, and then passes to the condenser. Additional heat is picked up in the condenser and the raw water passes into the deaerator. It is drawn from the deaerator by the hot-water pump and passed through the preheater into the first-effect evaporator. Continuous blowdown from the first-effect evaporator supplies feed water to the second-effect evaporator and a similar process supplies feed water to the third-effect evaporator. The blowdown from the third-effect evaporator is discharged to waste. Steam formed in the first effect passes through coils in the second effect, condenses and forms steam in the second effect. This steam passes through coils in the third effect, where it condenses forming more steam. The steam formed in the third effect is piped to the condenser where it is condensed to form distillate. The condensate from the coils of the second and third effect also goes to the condenser. Distillate from the condenser passes to the cooler and is then discharged for use.

condenser also receives the condensate from the second- and third-effect evaporators. All condensate is discharged from the condenser as distillate.

e. COOLER AND PREHEATER. The cooler and preheater are horizontal multipass tube-type heat exchangers. The cooler both cools the distillate for immediate use and heats raw water. The preheater heats the feed water to operating temperature. Steam vented from the first-effect evaporator passes around raw-water tubes, heating the raw water within them.

f. DEAERATOR. The deaerator is an open cylindrical tank divided into two sections: one is a reservoir for the evaporator-feed pump; the other receives preheated water from the condenser, provides the amount of water used for feed water, and discharges the excess to waste. The deaerator allows noncondensable gases dissolved in the raw water to escape into the atmosphere.

g. ENGINE. The engine is a single-cylinder hopper-type water-cooled gasoline engine. It supplies power to operate the raw-water pump, the evaporator-feed pump, the fuel-oil pump, and the blower of the burner assembly. The engine has protection against the entrance of sand and other abrasive materials.

h. RAW-WATER AND EVAPORATOR-FEED PUMPS. The raw-water and evaporator-feed pumps are all-bronze open-impeller centrifugal pumps. The raw-water pump supplies raw water to the unit. The evaporator-feed pump withdraws water from the deaerator, forces it through the preheater, and into the first-effect evaporator.

i. MOUNTING. (1) *Skid.* The welded-steel skid consists of runners turned up at each end with a closure plate between them.

(2) *Housing.* The housing consists of a metal top and metal-reinforced plywood-side covers. A canvas-covered metal basket on top of the unit holds accessory equipment.

123. Operation

See TM 5-2062 for detailed operating instructions.

a. Never light burner if water does not show in gauge glass.

b. Unit is operating correctly when—

(1) Fuel-oil consumption is 4 gph.

(2) Slight blue haze comes from stack.

(3) Distillate and blowdown flow are approximately equal.

(4) First-effect evaporator-feed temperature is between 200° and 210° F.

(5) Condenser vent gives off occasional wisp of steam.

(6) Distillate is clear and not salty.

(7) Engine speed is 850 rmp.

(8) Two or three inches of water are showing in first-effect-evaporator gauge glass.

124. Shutdown

a. **TEMPORARY SHUTDOWN.** For an emergency or temporary shutdown, it is advisable to retain as much heat in the unit as possible. (See TM 5-2062 for detailed instructions.)

b. **PROLONGED SHUTDOWN.** For prolonged shutdown or for temporary shutdown in freezing weather, drain unit completely.

Section IV. THERMOCOMPRESSSION DISTILLATION UNITS

125. General

The operation of each of the four thermocompression units used by the Army is described in the following paragraphs. Although the basic principle used in all units is the same, the two 3,000-gpd units are made by different manufacturers and differ in operation.

126. 1,200-GPD Unit

a. **FUNCTION OF PARTS.** The 1,200-gpd unit (figs. 100 and 101) consists of a compressor, an evaporator-condenser, a combination blowdown and distillate heat exchanger, a gasoline engine, an engine water cooler, an exhaust-gas heat exchanger, a raw-water pump, a distillate pump, necessary piping, valves, and control

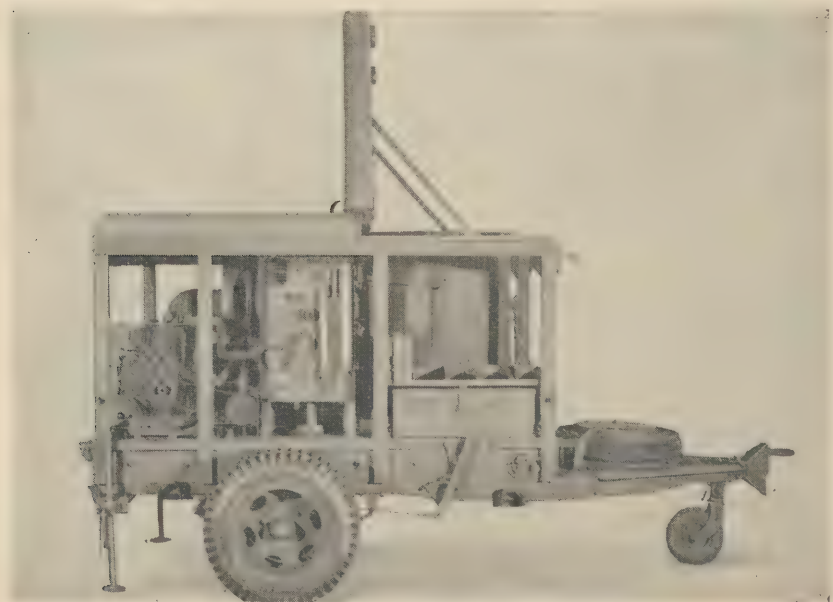


Figure 100. Trailer-mounted 1,200-gpd thermocompression distillation unit. This unit weighs 4,700 pounds, is 12 feet 7 inches long, 7 feet wide, and 6 feet 2 inches high.

gauges, and the mounting. A flow diagram for both the trailer- and skid-mounted units is shown in figure 102.

(1) *Compressor.* The positive-displacement-type rotary compressor is made of bronze. It draws steam from the steam dome of the evaporator-condenser, compresses it, and then discharges the compressed steam to the condenser section.

(2) *Evaporator-condenser.* The short vertical-tube-type evaporator-condenser has three sections: a bottom or raw-water receiving section, a heat exchanger or combined evaporating and condensing section, and a top or steam-dome section. Water which has passed through the various heat exchangers enters the bottom of the evaporator-condenser. It is carried up through the evaporator tubes by steam generated when part of the water in the tubes evaporates. A portion of the water which has not been converted to steam is discharged as blowdown and the remainder spills back into the bottom section of the evaporator. The steam formed passes into the steam dome, is compressed, and then discharged to the steam-condensing section around the vertical tubes. The steam is condensed and at the same time evaporates additional water within the tubes.

(3) *Blowdown and distillate heat exchanger.* The combination blowdown and distillate heat exchanger is a concentric-tube-type element, which removes all possible heat from the distillate and blowdown and transfers it to the incoming feed water. The heat exchanger is divided into a section for raw water and one for blowdown. The raw water and the blowdown flow through the inner tubes of their respective sections. Distillate flows through the

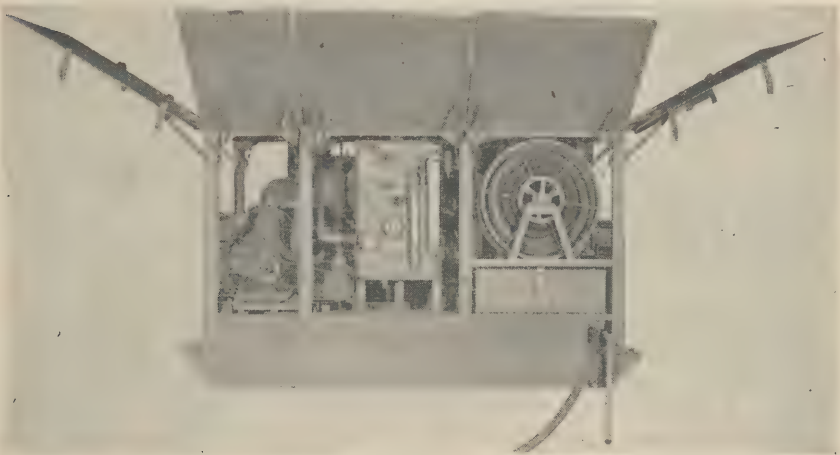


Figure 101. Skid-mounted 1,200-gpd thermocompression distillation unit. This unit weighs 4,300 pounds, is 7 feet 8 inches long, 4 feet 6 inches wide, and 5 feet 6 inches high.

spaces between the concentric tubes of the entire heat exchanger, alternating from the raw-water to the blowdown section. As it flows, it heats the incoming feed water and also picks up heat from the blowdown and transfers it to the feed water. One double tube of the heat exchanger is a vent condenser, condensing the vapors continuously given off from the evaporator steam chest. The non-condensable vapors pass through an opening to the atmosphere.

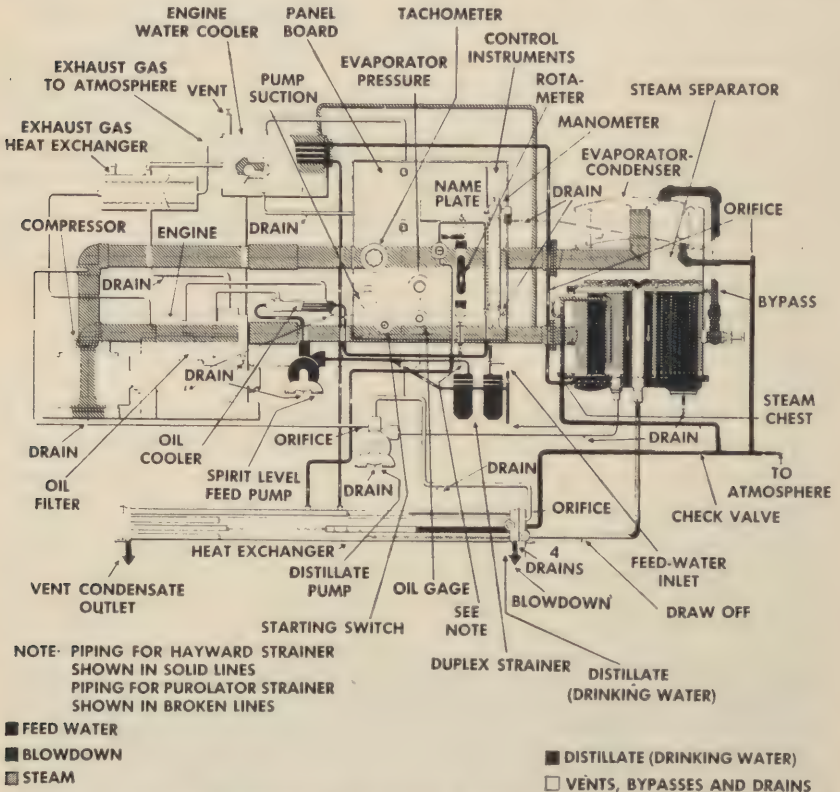


Figure 102. Flow diagram of 1,200-gpd thermocompression distillation unit. Raw water enters at the duplex strainer and is pumped through the oil cooler and rotometer to the blowdown and distillate heat exchanger. There it picks up heat from the distillate and the blowdown and from noncondensable gases vented from the evaporator-condenser. The water then passes through the engine water cooler, where it picks up additional heat and then enters the bottom of the evaporator-condenser. The steam formed in the evaporator-condenser is drawn into the compressor, compressed, and returned to the condensing section of the evaporator-condenser. The distillate is withdrawn from the evaporator-condenser and pumped into the blowdown and distillate heat exchanger. Part of the distillate is bypassed to the engine water cooler, where it is used as engine cooling water. Steam formed in the engine water cooler is piped into the discharge line from the compressor. Blowdown flows from the evaporator-condenser, passes through the blowdown and distillate heat exchanger, and is discharged to waste.

The heat exchanger is thoroughly insulated to minimize heat losses.

(4) *Engine.* The gasoline engine is an automotive-type water-cooled engine with a water-cooled exhaust manifold. It supplies power to operate the compressor and pumps, and supplies heat to the system.

(5) *Engine water cooler.* The engine water cooler is essentially a heat exchanger. The lower half of the cooler contains the engine water coolant (distilled water), the level of which is automatically controlled by a float-operated valve. Heat from the engine is transferred to the raw water within the tubes by steam produced from the engine water coolant. The water cooler is insulated.

(6) *Exhaust-gas heat exchanger.* In the exhaust-gas heat exchanger, heat is transferred from the engine exhaust gases to the engine cooling water circulating through the tubes of this heat exchanger.

(7) *Pumps.* The raw-water and distillate pumps are identical. They are single-stage turbine-type all-bronze pumps. The raw-water pump supplies raw-water feed to the unit, and the distillate pump removes distillate from the evaporator and pumps it through the compound heat exchanger.

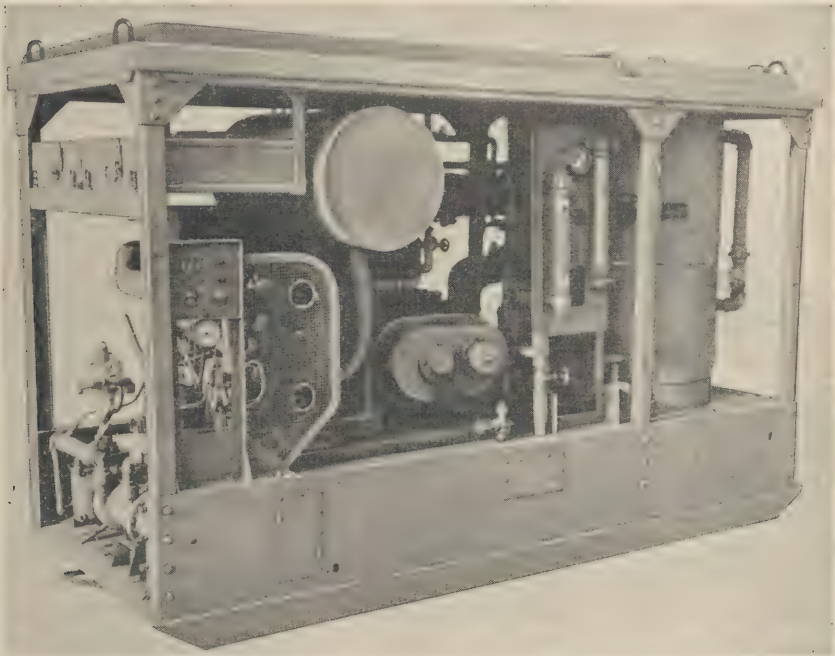


Figure 103. Skid-mounted 3,000-gpd thermocompression distillation unit (Badger). This unit weighs 7,500 pounds, is 9 feet 8 inches long, 4 feet 6 inches wide, and 6 feet 3 inches high.

(8) *Mounting. (a) Trailer.* The two-wheeled trailer has a fixed drawbar with retractable caster wheel.

(b) *Skid.* The steel skid and frame have members for mounting the component parts. The skid is provided with retractable pulling devices, and has a pair of runners with upturned ends with a closure plate between.

(c) *Canopy.* The unit is covered with a steel-top canopy supported on legs which fit into sockets in the skid. The legs and top also provide a base for lifting eyes on top of the unit. The sides are inclosed with removable plywood covers. A section of the canopy is hinged so the evaporator heat exchanger can be reached for scale removal.

b. OPERATION. See TM 5-2068 for detailed operating instructions.

c. SHUTDOWN. (1) *Temporary shutdown.* For temporary shutdown, see TM 5-2068 for detailed instructions.

(2) *Prolonged shutdown.* For prolonged shutdown or temporary shutdown in freezing weather, drain unit completely.

127. 3,000-GPD Unit (Badger)

a. FUNCTION OF PARTS. The 3,000-gpd unit (Badger) (fig. 103) consists of a compresor, an evaporator-condenser, a combination blowdown and distillate heat exchanger, a vent condenser, an engine, an engine water cooler, an exhaust-gas heat exchanger, a dual raw-water and distillate pump, necessary piping, valves, and control gages, and the mounting. A flow diagram is shown in figure 104.

(1) *Compressor.* The positive-displacement-type rotary compressor is made of bronze. It draws steam from the steam dome of the evaporator-condenser, compresses it, and then discharges the compressed steam to the condenser section.

(2) *Evaporator-condenser.* The short, vertical-tube-type evaporator-condenser has three sections: a bottom or raw-water section; a heat-exchanger or combined evaporating and condensing section; and a top or steam-dome section. Water which has passed through the various heat exchangers, enters the evaporator-condenser above the upper tube sheet of the heat exchanger section and passes down through the center of this section, through the return flow space surrounding the overflow (blowdown) pipe to the bottom of the evaporator-condenser. It is carried up through the evaporator tubes by steam generated when part of the water in the tubes evaporates. A portion of the water which has not been converted to steam is discharged as blowdown and the remainder spills back into the bottom section of the evaporator. The steam formed passes into the steam dome, is compressed, and then discharged to the steam-condensing section around the vertical tubes. The steam

is condensed and, at the same time, evaporates additional water within the tubes.

(3) *Blowdown and distillate heat exchanger.* The combination blowdown and distillate heat exchanger is divided into two sections, one for raw water and the other for blowdown. The heat exchanger removes all possible heat from the distillate and blowdown and transfers it to the incoming feed water. The raw water and the blowdown flow through the inner tubes of their respective sections.

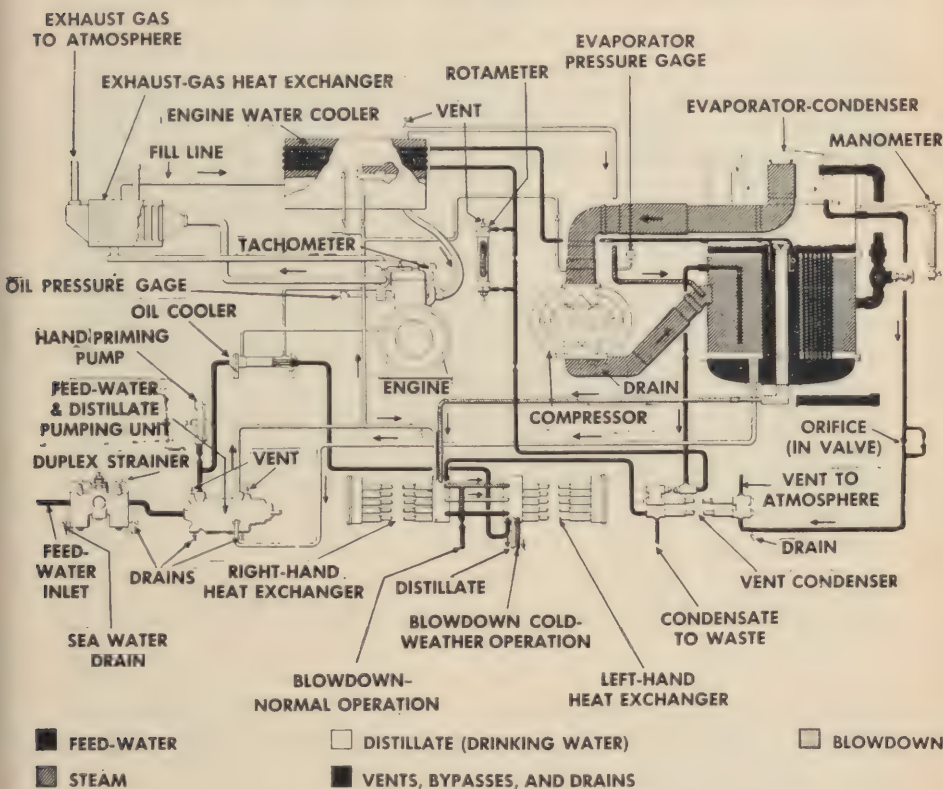


Figure 104. Flow diagram of 3,000-gpd thermocompression distillation unit (Badger). Raw water enters at the duplex strainer and is pumped through the oil cooler and into the blowdown and distillate heat exchanger, where it picks up heat from the blowdown and the distillate. It is then piped through the vent condenser and into the engine water cooler where it picks up additional heat. From the engine water cooler, the feed water is piped into the evaporator-condenser. The steam formed in the evaporator-condenser is compressed and discharged into the condenser section where it is condensed. The distillate is withdrawn from the evaporator-condenser and pumped into the blowdown and distillate heat exchangers. Part of the distillate is bypassed to the engine water cooler where it is used as engine cooling water. Steam formed in the engine water cooler is piped to the compressor discharge line. Blowdown flows from the evaporator-condenser, passes through the blowdown and distillate heat exchanger, and is discharged to waste.

Distillate, alternating from the raw-water to the blowdown section, flows through the spaces between the tubes of the entire heat exchanger. The distillate transfers its heat to the incoming feed water, and also picks up heat from the blowdown and transfers it to the feed water. The heat exchanger is thoroughly insulated to minimize heat losses.

(4) *Vent condenser*. The vent condenser is a concentric-tube heat exchanger similar to the combination heat exchanger. Raw water is forced through the inner tube, and vapor and steam along with air and noncondensable gases are vented through an opening to the atmosphere.

(5) *Engine*. The gasoline engine is an industrial-type four-cylinder water-cooled engine with a water-cooled manifold. It supplies power to operate the compressor and pumps and supplies heat to the system.

(6) *Engine water cooler*. The engine water cooler is essentially a heat exchanger. The lower half of the cooler contains the engine water coolant (distilled water), the level of which is automatically controlled by a float-operated valve. Heat from the engine is transferred to the raw water within the tubes by steam produced from the engine water coolant. The water cooler is insulated.

(7) *Exhaust-gas heat exchanger*. In the exhaust-gas heat exchanger, heat is transferred from the engine exhaust gases to the engine cooling water, which is circulated through the tubes of this heat exchanger.

(8) *Dual pump*. The raw-water and distillate pump is a dual closed-impeller centrifugal-type pump. The raw-water pump on one end of the housing and distillate pump on the other have a common shaft.

(9) *Mounting*. (a) *Skid*. The steel skid and frame have members for mounting the component parts. The skid is provided with retractable pulling devices, and has a pair of runners with upturned ends and a closure plate between.

(b) *Canopy*. The unit is covered with a steel-top canopy supported on eight legs which fit into sockets in the skid. The legs and top also provide a base for lifting eyes on top of the unit. The sides are inclosed with removable plywood covers. A section of the canopy is removable so the evaporator heat exchanger can be reached for scale removal.

b. OPERATION. See TM 5-2065 (when published) for detailed operating instructions.

c. SHUTDOWN. (1) *Temporary shutdown*. For temporary shutdown, see TM 5-2065 for detailed instructions.

(2) *Prolonged shutdown*. For prolonged shutdown, drain unit completely.

128. 3,000-GPD Unit (Cleaver-Brooks)

a. **FUNCTION OF PARTS.** The 3,000-gpd unit (Cleaver-Brooks) (fig. 105) consists of a compressor, an evaporator-condenser, a distillate and blowdown heat exchanger, a vent condenser, an engine, an exhaust-gas heat exchanger, an engine water cooler, a raw-water pump, a distillate pump, a blowdown pump, necessary piping, valves and control gauges, and the mounting. A flow diagram is shown in figure 106.

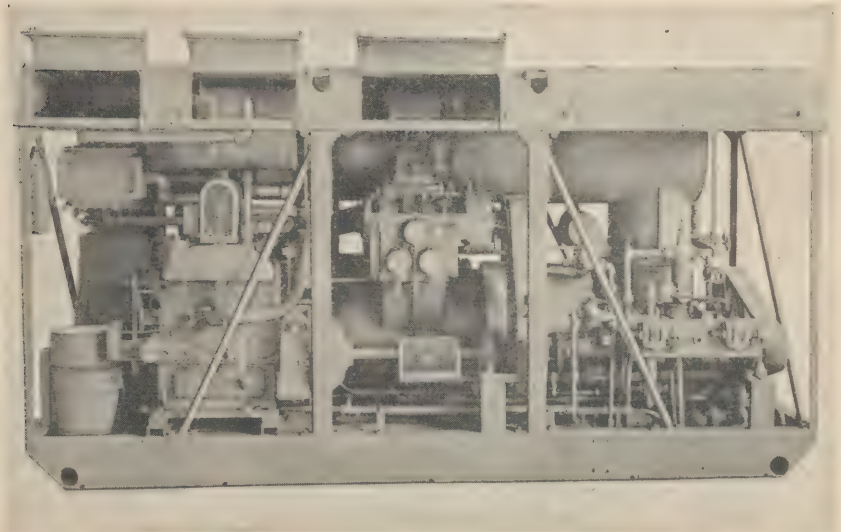


Figure 105. Skid-mounted 3,000-gpd thermocompression distillation unit (Cleaver-Brooks). This unit weighs 7,500 pounds, is 11 feet 2 inches long, 4 feet 2 inches wide and 5 feet 6 inches high.

(1) *Compressor.* The positive-displacement-type rotary compressor is made of anodized aluminum. It has a capacity of 670 cfm at 2,250 rpm. It draws steam from the vapor-separating space in the evaporator-condenser, compresses it, and then discharges the compressed steam to the condenser section.

(2) *Evaporator-condenser.* The evaporator-condenser consists of a heat-exchanger or condenser section, a circulating pump, and a flume or vapor-separating space. Raw water preheated in heat exchangers and in the vent condenser enters the flume section of the evaporator and passes to the circulating pump, which forces it through the tubes of the heat-exchanger section. The water then passes through the flume and returns to the pump. The circulating pump is installed internally in the system and has an oil-lubricated bearing. Part of the circulating raw water passing through the tubes is evaporated by compressed steam surrounding the tubes.

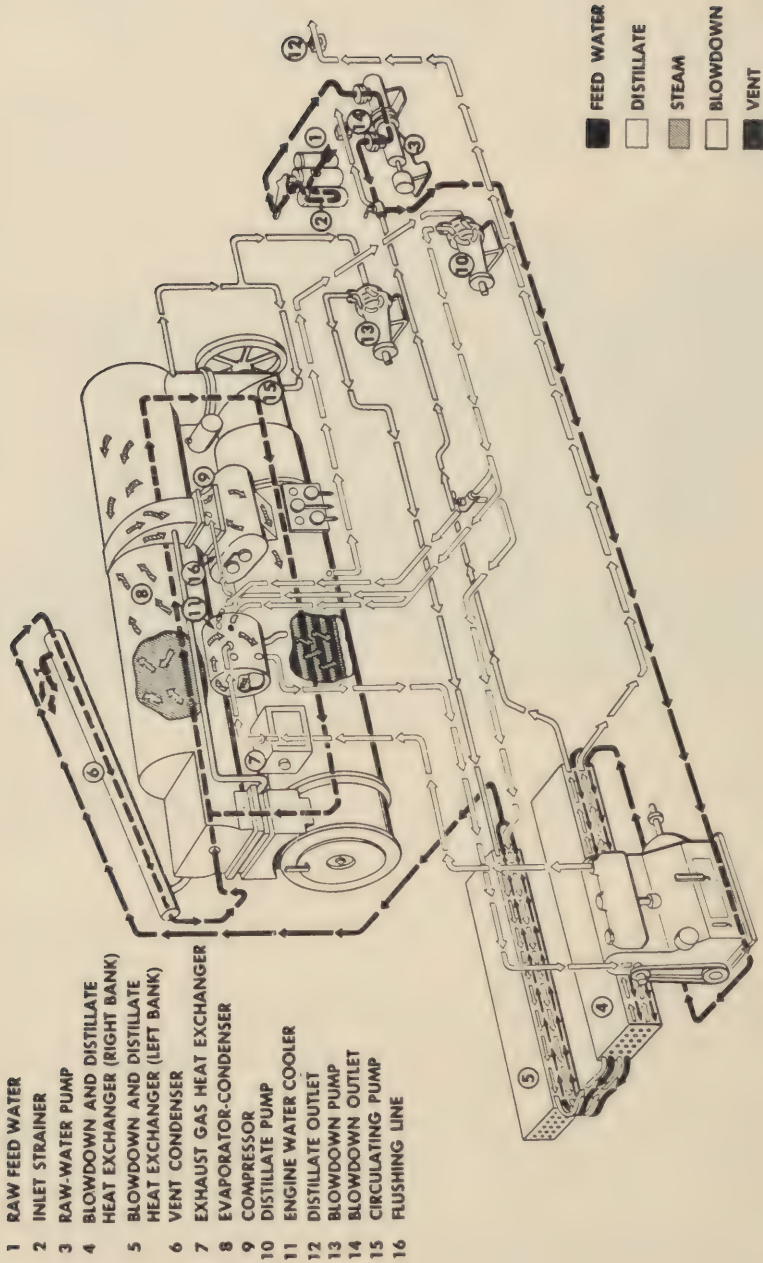


Figure 106. *Flow diagram of 3,000-gpd thermocompression distillation equipment (Clever-Brooks). Raw water enters the strainer (2) and is pumped through the engine oil cooler into the blowdown and distillate heat exchangers (4) and (5) where it picks up heat. It then passes through the vent condenser (6) where it picks up additional heat before entering the flume section of the evaporator-condenser (8). The steam formed in the evaporator condenser is withdrawn by the compressor (9), compressed, and returned to the condenser section where it is condensed. The distillate is withdrawn from the evaporator-condenser (8), pumped through the blowdown and distillation heat exchangers (4 and 5), and discharged to storage. Part of the distillate is bypassed to the engine water cooler (11), where it becomes engine cooling water. Steam formed in the engine water-cooler (11) is piped into the condenser section of the evaporator-condenser (8). The blowdown is pumped from the evaporator-condenser (8) to the blowdown and distillate heat exchangers (4 and 5) and is then discharged to waste.*

The steam is condensed and collected in the hot well of the condenser section.

(3) *Blowdown and distillate heat exchanger.* The combination blowdown and distillate heat exchanger, constructed in two sections, consists of tubes cast in aluminum. The ends of the tubes are manifolded for counterflow of distillate and blowdown to raw water, with raw water removing heat from the blowdown and distillate by conduction through the aluminum.

(4) *Vent condenser.* The vent condenser is a single-pass concentric-tube-type heat exchanger. Raw water is forced through the inner tube, and vapor and steam along with air and noncondensable gases are drawn into the space between the pair of tubes. The vapor and steam are condensed into distillate and returned to the hot well, leaving air and other noncondensable gases to escape through a vent.

(5) *Engine.* The gasoline engine is an industrial-type four-cylinder water-cooled engine with a water-cooled exhaust manifold. It supplies power to operate the compressor and pumps, and supplies heat to the system.

(6) *Exhaust-gas heat exchanger.* The exhaust-gas heat exchanger is of the fin-and-tube type. Exhaust gases pass in contact with the fins and around the tubes through which the engine cooling water flows.

(7) *Engine water cooler.* The engine water cooler is a horizontal 15-gallon cylindrical tank. Distilled water is pumped through a float valve from the distillate pump to the cooler, circulated through the engine jacket and exhaust-gas heat exchanger, and returned to the cooler as boiling water. Steam is disengaged from the water at the top of the cooler and passes to the condenser of the evaporator heat exchanger.

(8) *Raw-water pump.* The raw-water pump is a double-stage, self-priming, low-velocity pump consisting of a chrome-steel single-threaded helical rotor rotating in a double-threaded rubber stator. It supplies raw-water feed for the unit.

(9) *Distillate and blowdown pumps.* The distillate and blowdown pumps are identical single-staged turbine-type pumps of bronze. The distillate pump draws distillate from the hot well of the condenser, maintains the water supply to the engine cooling system, and discharges distillate through the heat exchanger to storage. To prevent excessive salt concentration, the blowdown pump discharges a set volume of water through the heat exchanger to waste. During starting it also recirculates evaporator feed water through the system.

(10) *Mounting.* (a) *Skid.* The iron toboggan type skid has a

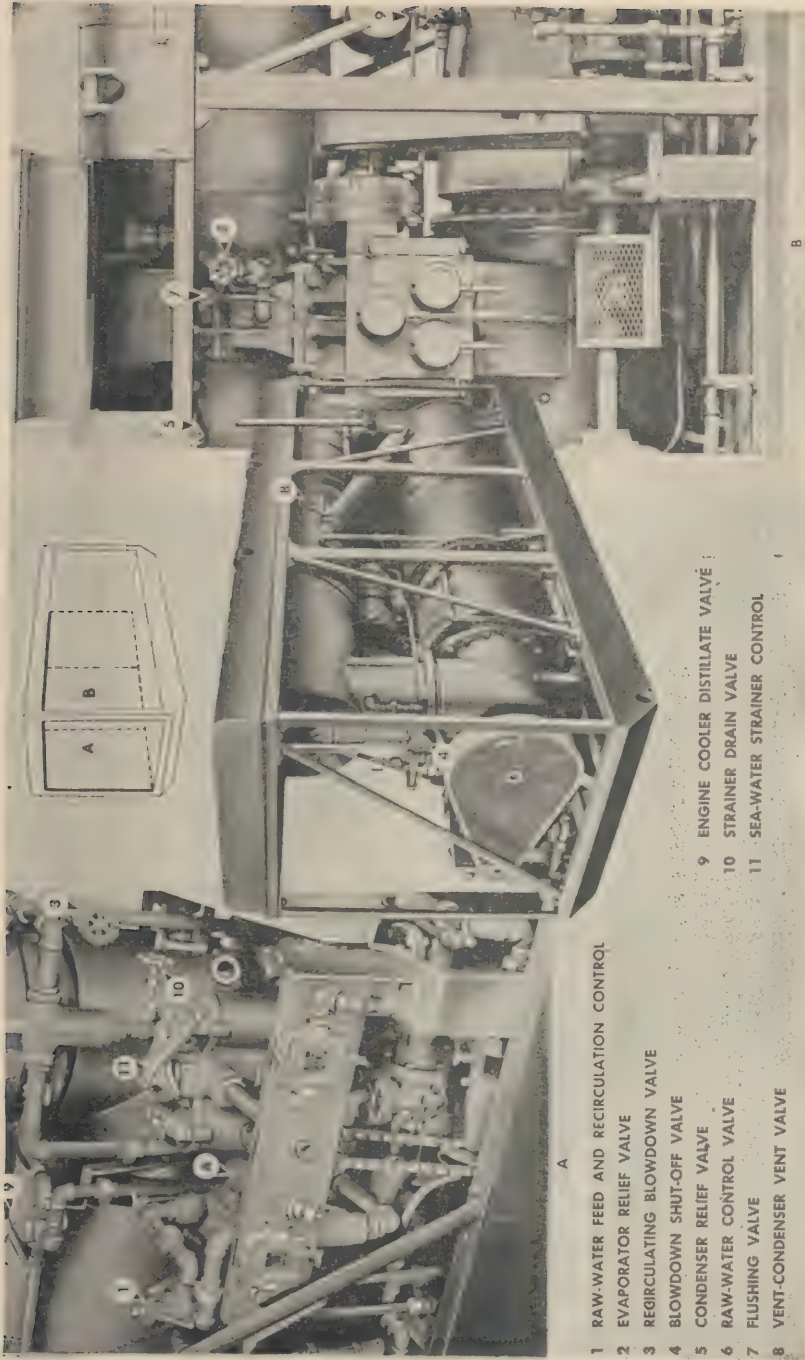


Figure 107. Valve locations and numbers on 3,000-gpd thermocompression distillation unit (Clever-Brooks).

flat steel bottom with turned-up ends and fixtures for attaching towlines.

(b) *Canopy.* The unit is covered with a steel-top canopy supported on eight legs fixed to the skid with diagonal bracing. The legs and top also provide a base for lifting eyes on top of the unit. The sides are inclosed with removable plywood covers.

b. OPERATION. Refer to TM 5-2069 (when published) for detailed operating instructions.

c. SHUTDOWN. (1) *Temporary shutdown.* For temporary shutdowns, refer to TM 5-2069 for detailed instructions.

(2) *Prolonged shutdown.* For long shutdowns, drain unit completely.

(3) *Shutdown in freezing weather.* When shutting down units for more than 1 hour in freezing weather, drain unit completely.

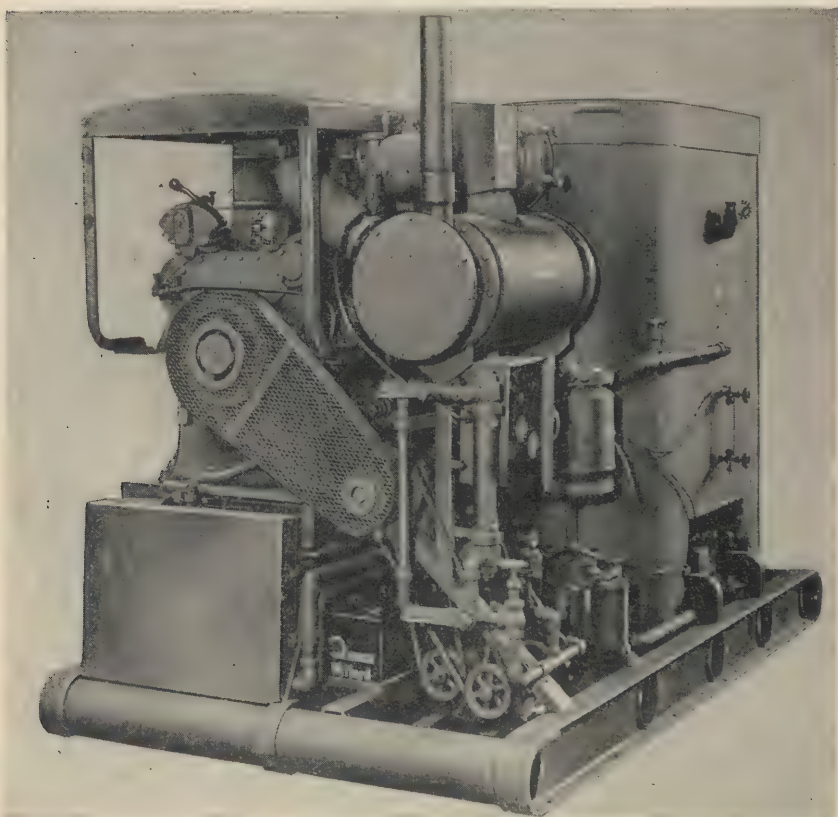


Figure 108. Skid-mounted 6,000-gpd thermocompression distillation unit. This unit weighs 13,600 pounds, is 9 feet 1 inch long, 5 feet 7 inches wide, and 6 feet 4 inches high.

129. 6,000-GPD Unit

a. **FUNCTION OF PARTS.** The 6,000-gpd unit (fig. 108) consists of a compressor, an evaporator-condenser, a distillate heat exchanger, a blowdown heat exchanger, a vent condenser, an engine, an exhaust-gas heat exchanger, an engine water cooler, a raw-water pump, a distillate pump, necessary piping, valves, and control gauges, and the mounting. A flow diagram is shown in figure 109.

(1) *Compressor.* The positive-displacement-type rotary compressor is made of bronze. It has a capacity of 1,215 cfm at 980 rpm. It draws steam from the steam space of the evaporator-condenser, compresses it, and then discharges it to the condenser section.

(2) *Evaporator-condenser.* The vertical-tube-type evaporator-condenser consists of three sections: a bottom or raw-water receiving section, a heat exchanger or combined evaporating and condensing section, and a vapor separator or steam-space section.

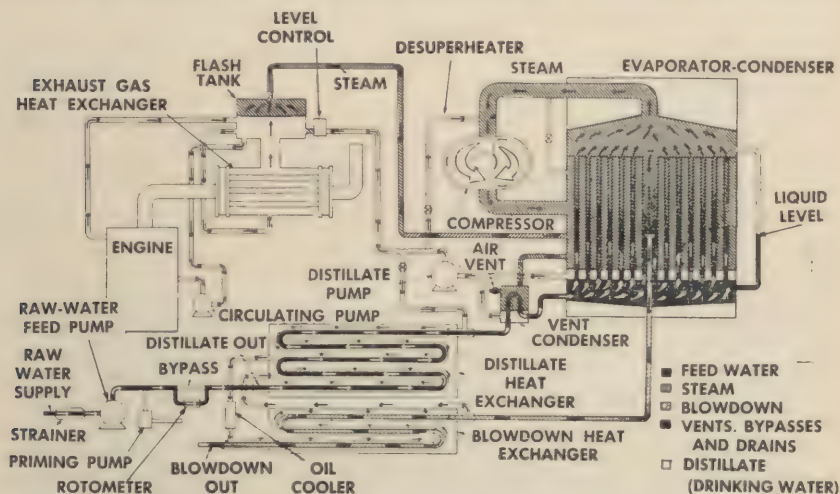


Figure 109. Flow diagram of 6,000-gpd thermocompression distillation unit. The raw water enters the strainer and is pumped to the distillate heat exchanger where it picks up heat from the distillate. The water then passes through the vent condenser, where it picks up additional heat before it enters the evaporator-condenser. Steam formed in the evaporator-condenser is drawn into the compressor, compressed, and discharged into the condenser section where it is condensed. The distillate is withdrawn from the evaporator-condenser, pumped into one section of the distillate heat exchanger, and then through the oil cooler into the blowdown heat exchanger. The distillate picks up heat in the blowdown heat exchanger and passes back to the distillate heat exchanger, where this heat is transferred to the incoming feed water. Part of the distillate is bypassed to the engine water cooler and becomes engine cooling water. Steam formed in the engine water cooler is piped into the condenser section of the evaporator-condenser. The blowdown is withdrawn from the evaporator-condenser, passes through the blowdown heat exchanger, and is discharged to waste.

Water which has passed through the various heat exchangers enters the bottom of the evaporator-condenser. It is carried up through the tubes by steam, forms more steam, and after passing through the tubes spills over into the bottom section. The steam formed passes into the steam space, is compressed, and then discharged to the steam-condensing section around the tubes. The steam divides equally into two condensing sections, is condensed and at the same time evaporates additional water within the tubes.

(3) *Distillate and blowdown heat exchangers.* The distillate and blowdown heat exchangers are two separate elements. Both are of the multipass concentric-tube type. Both remove all possible heat from the distillate and blowdown and transfer it to the raw water. Raw water is confined to the distillate heat exchanger and blowdown is confined to the blowdown heat exchanger. Distillate passes into one side of the distillate heat exchanger, gives up its heat to the raw water, passes to the blowdown heat exchanger where it recovers heat from the blowdown, and returns to the other side of the distillate heat exchanger. In this way, the heat of the blowdown is transferred to the raw water.

(4) *Vent condenser.* The vent condenser is of the shell and tube type. Feed water makes three passes through the tubes. Air, steam, and noncondensable gases from the evaporator-condenser are discharged into the area around the tubes. The steam is condensed, and air and noncondensable gases are vented through a needle valve to the atmosphere.

(5) *Engine.* The engine is an industrial-type full-Diesel four-cylinder water-cooled engine with a water-cooled exhaust manifold. It develops 40 hp at 980 rpm. It supplies power to operate the compressor and pumps, and supplies heat to the system.

(6) *Exhaust-gas heat exchanger.* The exhaust-gas heat exchanger is a shell and tube type. Engine exhaust gases pass through the inside of the tubes, heating the distilled water circulating through the exchanger from the engine water cooler.

(7) *Engine water cooler.* The engine water cooler is a horizontal cylindrical tank. Distilled water is supplied through a float-valve-type water-level control. The engine circulating pump transfers the water from the cooler, through the engine and the exhaust-gas heat exchanger, and back to the cooler. Steam formed is carried to the evaporator-condenser steam space.

(8) *Pumps.* The raw-water and distillate pumps are single-stage closed-impeller straight centrifugal pumps constructed of bronze where in contact with water. The raw-water pump supplies raw-water feed to the unit, and the distillate pump removes distillate from the evaporator-condenser and pumps it through the heat exchangers.

(9) MOUNTING. The skid and frame are of structural steel sections and support all component parts.

b. OPERATION. See TM 5-2063 (when published) for detailed operating instructions.

(1) If exhaust temperature exceeds 750° F., engine sounds overloaded, or speed decreases, open evaporator-bypass valve (fig. 110) immediately.

(2) Never operate unit with less than 8.5-gpm flow of feed water.

c. SHUTDOWN. (1) *Temporary shutdown.* For temporary shutdown, see TM 5-2063 for detailed instructions.

(2) *Prolonged shutdown.* For prolonged shutdown or temporary shutdown in freezing weather, drain unit completely.

Section V. PRODUCTION EFFICIENCY

130. Introduction

Distillation equipment must be properly maintained if it is to be operated continuously and efficiently at rated capacity. This section discusses production efficiency, expedient repairs, shutting down equipment, and cold-weather operation.

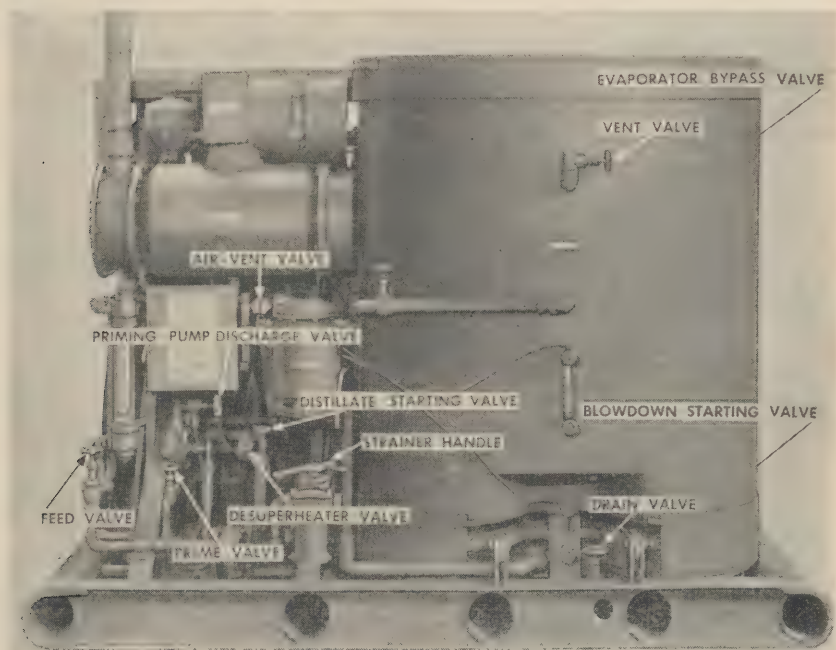


Figure 110. Valve locations on 6,000-gpd thermocompression distillation unit.

131. Precautions

a. GENERAL RECOMMENDATIONS. In addition to normal precautions, the following general recommendations apply to both oil-fired and thermocompression-type units.

(1) Use raw water as free of silt, sand, or any other foreign material as possible. Have sufficient settling and reservoir capacity available to insure maximum settling.

(2) Be sure that engine and burner fuel are free of water and foreign matter. Strain if necessary, and store in closed container.

(3) Keep both moulded-rubber and sectional-type belting free of grease, fuel oil, or gasoline. Sectional belting is subject to shrinking when wet and must be kept dry.

(4) Keep shaft setscrews in sheaves and couplings tight. Take special care of vari-pitch sheaves. Keep setscrews tight and threaded hubs clean and protected against corrosion.

(5) Never force control and shutoff valves. Keep valve-stem packing snug but not so tight it binds the stem. Be sure to lubricate plug valves with the proper grease, using enough to keep them free and tight.

(6) Keep piping and fittings tight and free of leaks. Keep all piping supports and clamps tight to eliminate vibration.

(7) Maintain pump-shaft seals with care. Check to be sure the packing follower always fits squarely into the gland. When sufficient packing is in the gland and it is drawn up finger tight, adjustment is correct if a small quantity of water passes through the gland.

(8) Keep gauges and thermometers clean and do not flush with or place in water. Use wrench to remove or replace a gauge. Do not apply force to the case.

(9) Do not run pumps with a closed discharge. Always keep control valve open slightly and discharge some water.

b. OIL-FIRED UNITS. The following preventive maintenance suggestions apply to oil-fired equipment.

(1) Blow off safety valves once a day.

(2) Blow down 2 or 3 gallons from each evaporator every 10 hours of operation.

(3) Drain fuel-oil strainers once a day, and more frequently if necessary.

(4) Remove any lump deposits of carbon from combustion chamber of fire tube.

(5) Keep burner assembly clean and handle it with care. Clean nozzle tips by washing them in fuel oil and blowing them out. Use a sharp-pointed stick to remove any deposit from orifice.

c. THERMOCOMPRESSION UNITS. The following precautions apply to thermocompression-type equipment.

(1) Adjust compressor steam-shaft seals only when abnormal quantities of steam are being discharged. Maintain enough packing for a snug fit. Fit follower squarely and take up nuts finger tight.

(2) Do not overload engine by attempting to shorten starting period. Do not run engines above operating speed specified.

(3) Preserve and protect all insulation from water and grease.

132. Common Operating Troubles

The list below gives suggestions for locating failures in both oil-fired and thermocompression-type units.

a. ENGINE. Consult Technical Manual.

b. PUMP. Consult Technical Manual.

c. OIL-FIRED EQUIPMENT. (1) *Burner failure*. Burner failure may be caused by lack of fuel, fuel-pump failure, dirty or clogged nozzle, broken fuel line, pressure-regulator failure, or improper supply of air resulting from change in assembly relationship of burner parts.

(2) *Incomplete combustion*. Black smoke from stack indicates incomplete combustion usually caused by a slipping blower belt, damper not open far enough, improper supply of air, or too-high fuel pressure.

(3) *Low distillate output*. Low distillate output may be caused by too little fuel burned, burner failure, incomplete combustion, heavy scale on fire tube of first effect and coils of second effect, low first-effect feed-water temperature, or too much blowdown.

(4) *High evaporator pressures*. High evaporator pressures may be caused by heavy scale on evaporator heat exchangers, burning too much fuel, or insufficient blowdown.

(5) *Salt in distillate (priming)*. Priming may be caused by burning too much fuel, too high a water level in evaporator, not enough blowdown, improperly adjusted condensate regulator valves, broken tube in condenser or cooler, or leak in condenser or cooler tube sheets.

d. THERMOCOMPRESSOR EQUIPMENT. (1) *Compressor seizure*. Compressor seizure may be caused by foreign matter inside compressor or by failure to flush aluminum compressor (3,000-gpd unit) before shutting down.

(2) *High compressor discharge pressure*. High compressor discharge pressure may be caused by unvented air in system, heavy scale on heat exchanger, or engine and compressor running too fast.

(3) *High pressure in evaporator*. High pressure in evaporator may be caused by insufficient raw-water feed, high compressor discharge pressure, or an open evaporator bypass valve.

(4) *Difficulty in putting unit into operation.* Difficulty in putting unit into operation may be caused by heavy scale in evaporator heat exchanger, too much feed water, closed vent condenser valve, or engine and compressor running too slow.

(5) *Salt in distillate (priming).* Priming may be caused by too high a water level in evaporator, too much feed water, not enough blowdown, plugged blowdown outlet, broken tube in distillate heat exchanger, or leak in distillate heat-exchanger tube sheets.

133. Expedient Repairs

Equipment should be repaired promptly and completely while damage is minor and before major failures develop. Equipment should be reconditioned as often as necessary to keep it in first-class shape. In emergencies, the temporary repairs discussed below may be used.

a. **TUBE FAILURES, TUBULAR-TYPE HEAT-EXCHANGER UNITS.** If a tube fails in any heat exchanger or in heat-exchanger elements having several tubes in one pass, drive a wood plug into each end of the broken tube and block off the break. Replace the tube as soon as possible. If one of the coil elements of the second or third effects of oil-fired equipment fails and no spares are available, plug the manifold openings of the poor coil.

b. **ENGINE FAILURES.** If an engine fails or is damaged and replacement parts are not available, substitute a suitable engine.

(1) With oil-fired equipment use any source of power that maintains proper pump and blower speeds. A 2-hp electric motor will power any of the three units.

(2) Engines of thermocompression-type units can be replaced only by water-cooled engines of equal or greater horsepower. The engine used must be made an integral part of the unit, because the engine heat is necessary for operation. In an emergency, the water-cooled exhaust manifold can be omitted.

c. **RAW-WATER PUMP FAILURES.** If a raw-water pump fails and no spares or parts are available, use a separate booster to deliver raw water to the unit under pressure.

d. **FREEZING OF ALUMINUM COMPRESSORS.** If aluminum compressors of the 3,000-gpd thermocompression unit are not flushed when shut down, they may bind or seize because of salt deposit. If this happens, pour hot distilled water into the compressor suction vent and let it drain through the compressor into the condenser. Rotate shaft slightly in each direction until free. Do not force.

e. **ENGINE EXHAUST-GAS HEAT EXCHANGER.** If the exhaust-gas heat exchanger fails, remove it and continue to operate the unit.

This can be done because under most climatic conditions thermo-compression type units will produce distillate without the ex-changer.

134. Shutting Down

When shutting down distillation equipment temporarily or for short periods, see proper Technical Manual for each unit.

135. Cold-Weather Operation

Freezing temperatures have little effect on distillation-equipment performance. However, in extreme cold or when high winds are blowing, side panels or other protective shields must be used to prevent the equipment's freezing. No antifreeze can be used in the water-cooled engines, as engine water of the hopper-cooled engine of the 2,500-gpd triple-effect evaporates too rapidly and engine cooling systems of thermocompression-type units are part of the distillation system. All cold-weather shutdowns are considered permanent and the unit must be completely drained to prevent equipment icing up.

Section VI. SCALE

136. General

In distillation, a large portion of the dissolved salts remain in solution and are carried to waste by the continuous blowdown. Other salts, primarily carbonates and some sulfates, become insoluble at the evaporating temperatures and form a scale on the fire tubes, coils, and tubes of heat-exchanger elements. This scale must be removed periodically, because it retards heat transfer and thereby increases pressures and temperatures and reduces output and economy. Generally, both manual and chemical cleaning are used to remove scale. A thermal cracking process is incorporated in the design of 2,000- and 5,000-gpd oil-fired units to remove scale on the second-effect evaporator coils.

137. Oil-fired Distillation Equipment

a. GENERAL. Oil-fired distillation units normally require de-scaling after about 300 hours of operation. However, this interval and the method used are not fixed, and the operating characteristics of the particular units and the type of scale formed are the determining factors. Oil-fired units must be cleaned when—

- (1) Output is 20 percent below rated capacity.

(2) First-effect-evaporator steam pressure reaches 15 pounds for 2,000-and 5,000-gpd units or 17 pounds for 2,500-gpd units.

(3) Economy is low.

(4) Equipment is shutdown for extended periods.

b. MANUAL CLEANING. Scale is removed manually by brushing, chipping, or scraping deposit from fire tubes; brushing or striking second- and third-effect evaporator coils; and drilling, reaming, or brushing condenser, cooler, and preheater tubes. Note that only the 2,500-gpd triple-effect unit has a third-effect evaporator and a preheater. For detailed instructions, see proper Technical Manual for each unit.

c. CHEMICAL CLEANING. Scale can generally be removed satisfactorily by an acid solution, the best solution for field use being a water solution of sodium bisulfate (sodium acid sulfate). Best results are attained if the acid-soluble carbonate scales predominate or are present in large enough quantity to break up and carry along the less soluble sulfate scales. For detailed procedures, see proper Technical Manual for each unit.

d. THERMAL CRACKING. The thermal cracking process used to descale the second-effect evaporator coils of 2,000- and 5,000-gpd units is particularly effective in removing some types of hard, brittle scale. Thermal cracking consists of dousing the hot steam-filled coils with cold water. This causes the metal coils to expand and contract, and actually cracks off the scale. During each 24 hours of operation, these units should be descaled by thermal cracking.

138. Thermocompression Distillation Equipment

a. GENERAL. Like oil-fired equipment, thermocompression distillation units normally require descaling after about 300 hours of operation. However, the exact interval and the method used can be determined only after experience with the particular type scale that forms. Thermocompression equipment requires descaling when—

(1) Output has dropped 10 percent.

(2) Engine becomes overloaded.

(3) Pressure differential between compressor suction and discharge exceeds 3 pounds.

(4) Economy is low.

b. MANUAL CLEANING. For detailed procedures, see proper Technical Manual for each unit.

c. CHEMICAL CLEANING. Units should be chemically cleaned after each 300 hours of operation. (See par. 137*c*.) For detailed procedures, see proper Technical Manual for each unit.

Section VII. MISCELLANEOUS USES OF OIL-FIRED EQUIPMENT

139. General

All types of oil-fired distillation equipment can be used for such purposes as heating water for showers and producing steam for disinfecting clothes or other purposes. Operating principles for all units are the same as those outlined below for the 2,500-gpd triple-effect distillation unit.

140. Uses of 2,500-GPD Triple-Effect Distillation Unit

a. USE AS SIX-HEAD SHOWER-BATH HEATER. Following the flow diagram (fig. 111), the 2,500-gpd unit is put into operation as a shower-bath heater as follows:

- (1) Connect water hose from shower head to valve No. 11 and open valve wide.
- (2) Remove plug tee in line to valve No. 11. Remove boiler-feed thermometer and replace it with plug. Place boiler-feed thermometer in tee in line to valve No. 11.
- (3) Close valves Nos. 3, 5, 6, and 8.
- (4) Close all drainage points.
- (5) Check all lubrication points.
- (6) Fill engine hopper with water.
- (7) Start engine. Check pressure of cold-water pump by opening petcock in discharge line.

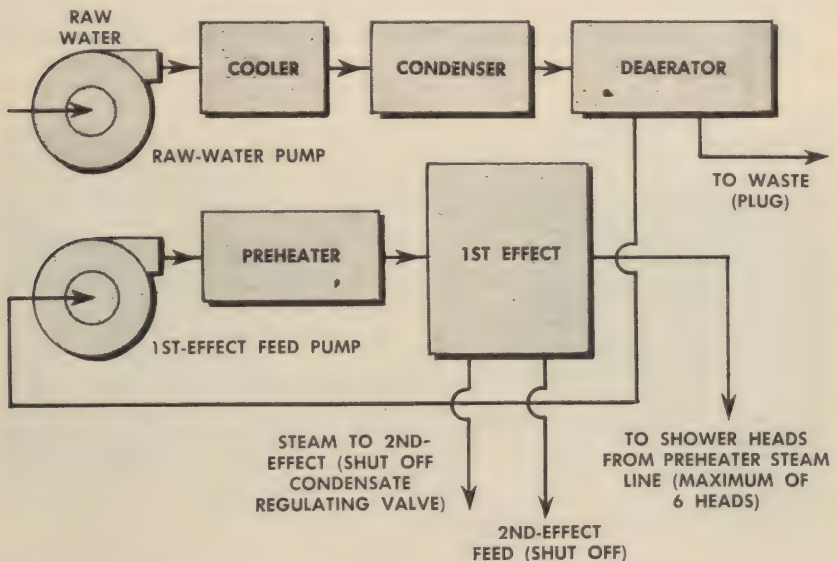


Figure 111. Flow diagram of 2,500-gpd triple-effect distillation unit used as heater. Note directions in parentheses.

(8) Open valve No. 2 wide and open valve No. 1 to supply water to hot-water pump.

(9) Light burner when water begins to rise in boiler gauge glass. Allow water to fill boiler and overflow through valve No. 11.

(10) When water temperature reaches 110° F., shut off burner for 15 minutes. Relight burner just long enough to keep water at desired temperature. (A test made with raw water at 50° F. indicated that 9 minutes was about enough.) Repeat cycle.

b. USE AS STEAM GENERATOR. Figure 112 shows the 2,500-gpd unit used as a steam generator, supplying steam to a delousing and sterilizing box constructed of the plywood side panels of the unit. Following the flow diagram, the unit is put into operation as a steam generator as follows:

(1) Connect water hose from auxiliary steam take-off valve No. 11 to apparatus requiring steam. Open valve as required.

(2) Close valves Nos. 3, 5, 6, and 8.

(3) Close all drainage points.

(4) Check all lubrication points.

(5) Fill engine hopper with water.

(6) Start engine. Check pressure of cold-water pump by opening petcock in discharge line.

(7) Open valve No. 1 to circulate cold water through condenser and to fill deaerating pan.

(8) Open boiler fill and feed valve No. 2.

(9) Light burner when there are 2 inches of water in water gauge glass.

(10) Adjust valve No. 2 so there are 2 inches of water in boiler gauge glass.



Figure 112. Use of 2,500-gpd triple-effect distillation unit as a steam generator. Steam box is constructed of side panels of unit.

Section VIII. EXPEDIENT DISTILLATION

141. General

When necessary, expedient stills can be built to produce potable water. All that is needed is a source of heat, a method of forming and collecting steam, and some kind of condenser. The efficiency of such expedients depends on the materials available and the ingenuity of the designer.

142. Expedient Distillation

Figures 113, 114, and 115 illustrate expedient distillation apparatus. In expedient distillation, sufficient vapor-separating space must be provided to prevent carryover of salt with the steam. Care must also be taken to avoid getting salt in the distillate through the expedient means used to condense the steam. To avoid building up steam pressure and endangering personnel, never close off or use a valve in the distillate line.

a. Figure 113 shows an expedient made of an empty fuel drum or oil barrel, $\frac{3}{4}$ - and 2-inch pipe, and valves. To operate the unit, fill the drum with water to the level of the overflow pipe and start a fire under the drum. When the water boils, the steam passes through the condenser. When starting, keep the feed valve closed until steam appears at the distillate outlet. Then pump water into the cooling-water inlet, adjusting the feed valve so the water level remains constant when the water-level control valve is barely open. Discharge the remaining cooling water to waste.

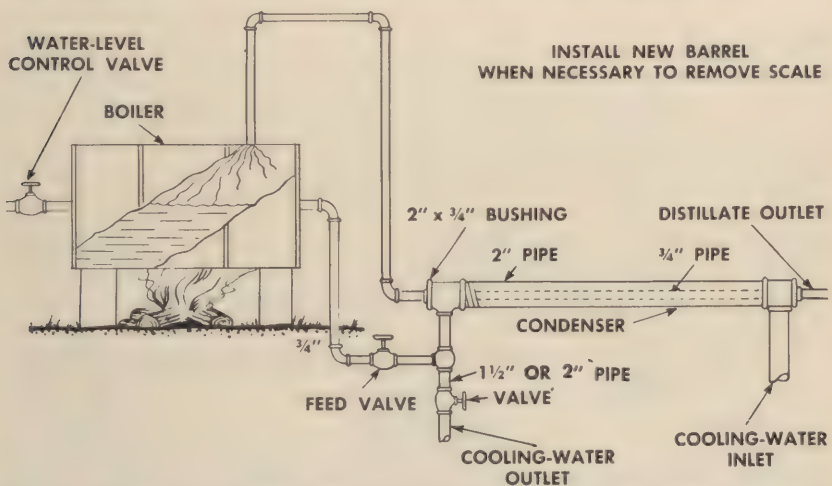


Figure 113. Expedient distillation apparatus consisting of an empty fuel drum, $\frac{3}{4}$ - and 2-inch pipes, and valves.

b. Figure 114 shows a method of improving the distillation equipment described in *a* above. The water cooler is constructed exactly like the condenser and serves both to cool the distillate and to heat the feed water. To keep the feed water as hot as possible, use only enough water to cause complete condensation.

c. Figure 115 shows an expedient using a long stretch of pipe as a condenser. Condensation can be made more complete by bending the pipe into curves and immersing it in a pit full of water.

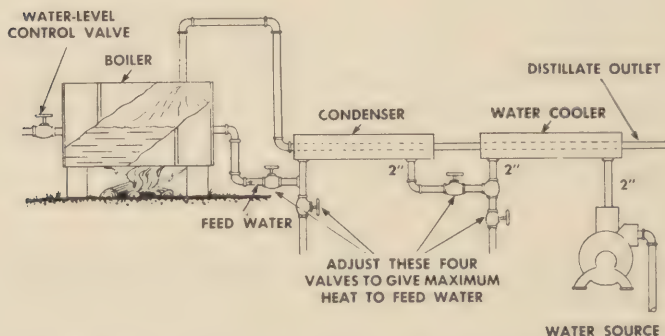


Figure 114. Expedient distillation apparatus improved by the addition of a distillate cooler. The condenser and cooler are identical with that shown in figure 113.

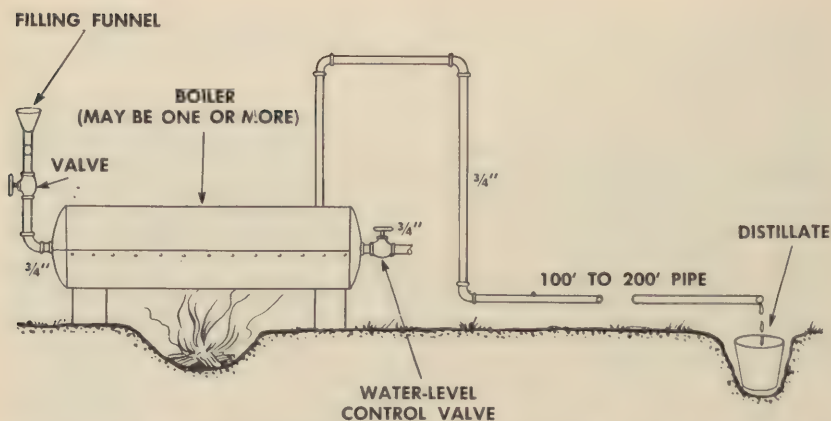


Figure 115. Expedient distillation apparatus consisting of a boiler, $\frac{3}{4}$ -inch pipe, and valves. For more complete condensation, the pipe can be immersed in water.

CHAPTER 6

WATER SUPPLY INSTALLATIONS

Section I. RECONNAISSANCE FOR WATER SOURCES

143. General

a. This section discusses the characteristics of satisfactory water sources and water points and the three phases of reconnaissance. Wherever possible, existing installations should be utilized.

b. Reconnaissance for water sources is a special engineer mission. It includes preliminary planning, ground reconnaissance, and reports; all three phases must be complete before a site can be selected. Ground reconnaissance or field observation is classed as advance reconnaissance when conducted by front-line units and as higher echelon reconnaissance when conducted by reserve units.

144. Water Sources

A satisfactory water source is one with a natural supply of water large enough to supply all needs of using troops and of such quality that it can be readily purified by available equipment.

a. Sources are classified as follows:

- (1) Surface water: streams, lakes, and rivers.
- (2) Ground water: wells and springs.
- (3) Sea water.
- (4) Rain water.
- (5) Dew: condensation on cool surfaces.
- (6) Vegetation: coconut, wild pineapple, and cactus.
- (7) Snow and ice.

b. The types of water source most frequently found in various climates are listed below:

- (1) Humid, temperate climate: surface and ground water.
- (2) Arid climate: ground water and minor sources.
- (3) Tropical climate: surface water, ground water, and minor sources.
- (4) Coral islands: ground and sea water.
- (5) Arctic climate: surface water, ice, and snow.

145. Water Points

A water point is a water source developed for military use. In

selecting a satisfactory water point, information on the subjects discussed below must be gathered and evaluated before a choice is made.

a. QUANTITY OF WATER. There must be enough water immediately available to meet current needs. (See table I for water requirements.) The quantity ultimately available after developing the point is important to higher echelons and should be estimated and reported as part of advance reconnaissance.

b. QUALITY OF WATER. Water should be clear and unpolluted. If the source is turbid, pretreatment (par. 36) becomes necessary. If a source contaminated with amoebic cysts or cercariae of schistosomes must be treated with portable or mobile water purification sets, pretreatment followed by filtration at reduced rates is essential.

c. COMMUNICATIONS. A satisfactory water point must be accessible to both vehicles and personnel. A good road net with turn-arounds at the water point and an adequate parking area are particularly desirable features.

d. SITE CONDITIONS. Where two or more sites meet the above requirements, selection is based on site conditions. The following considerations are discussed in order of importance:

(1) *Security.* The site should provide good cover and concealment and be a safe distance from artillery and aerial targets.

(2) *Drainage.* The site should be on high, porous ground to prevent its becoming swampy with use. Failure to consider drainage inevitably leads to excessive maintenance problems later. Units moving up to previously occupied water points should carefully check the drainage, as tactical considerations may have forced advance units to disregard this factor.

(3) *Bivouac for personnel.* A satisfactory bivouac area should be provided, since purification unit operators must live near the water point. This area should be near enough so operators not on duty are available in emergencies, yet far enough away to maintain proper sanitation of the water source. The bivouac area must be downstream of the water point to prevent contamination of the water source. Several days' supply of field rations should be kept for emergency use at every water point.

146. Preliminary Planning

a. INTELLIGENCE STUDIES. Before entering a new area, existing reports should be consulted as they often contain valuable information about water resources. Before beginning a field reconnaissance, the engineering and tactical data available at unit headquarters should also be studied. The following reports contain useful water information:

(1) *Climatic data and maps.* Weather reports and summaries have been collected and published for most portions of the world. They furnish data about the quantity of water which may be expected in any locality.

(2) *Geologic data and maps.* Geologic reports and maps are especially valuable for locating ground water. (See TM 5-296.)

(3) *Medical surveys.* War Department Technical Bulletins published by the Medical Department give valuable information on the water supply systems and the water-borne diseases which may be encountered in various theaters of operation. (See FM 21-6.)

(4) *Intelligence surveys.* Published intelligence summaries contain extensive information on water in specific areas of military operation and give the best data available at the time they were printed. The reports listed below include maps of topographic and geologic features, ground-water tables, data on municipal water systems, and climatic data. The more important reports are:

- (a) *Strategic Engineering Studies. Terrain Intelligence.*
Military Intelligence Division
Office, Chief of Engineers, US Army.
- (b) *Engineering Planning Data.*
Office, Chief of Engineers, US Army.
- (c) *Joint Army-Navy Intelligence Studies.*
Joint Intelligence Study Publishing Board.
- (d) *Topographic intelligence studies.*
Office of Strategic Services, Research and Analysis Branch.
- (e) *Reports on water resources data.*
Bureau of Yards and Docks, US Navy Department.
- (f) *Field monographs on various countries.*
Division of Naval Intelligence, US Navy Department.

Note. British sources of general information include the Inter-service Topographical Department reports and the Inter-service Information Series.

(5) *Field reports.* Field reports are the most important and reliable source of information on water resources in an area. Unlike the intelligence surveys issued and published in the United States, these reports contain summaries of the latest observations. In division or higher units, G-2 is the source of these reports which include reconnaissance reports, results of prisoner-of-war interrogations, tactical data, and native interrogations, records, and reports. In the engineer combat battalion, S-4 should have the latest information on water requirements.

b. MAP STUDIES. Before actual ground reconnaissance, all existing maps and aerial photographs of the area should be studied to obtain the following information:

(1) *Locations of possible sources.* Maps are especially valuable for locating surface water sources. Places where a road crosses or runs near a stream or pond are always possible water points. A study of drainage lines is helpful in areas where no streams are indicated.

(2) *Sources of pollution and contamination.* Water sources downstream of human habitations are subject to contamination. If possible, place water points upstream from villages whether inhabited or abandoned.

(3) *Communications.* Road nets are best shown on a map.

Note. Most military maps are incomplete and inaccurate especially when representing "works of man." If maps were perfect pictures of the earth's surface, ground reconnaissance would be unnecessary. *Do not depend too much on maps; a ground reconnaissance must always be made.*

c. ROUTE AND TIME SCHEDULES FOR GROUND RECONNAISSANCE. Before making a ground reconnaissance, it is desirable to decide on a route and time schedule. Without this preliminary planning, which should be done with a map at hand, it is rarely possible to cover all the ground. Once the time schedule is set up, write the times of arrival and departure for selected points on the reconnaissance map and follow the schedule closely.

147. Ground Reconnaissance

Actual ground observation is the only positive way of getting accurate information from which to select a water point. When conducting a ground reconnaissance, *take notes; memory alone cannot be depended on.* A sketch of the site properly keyed to a map is invaluable. Remember that higher authority has to select water sites from the *reported* data. Above all, remember that speed is vital. Methods of collecting information in the field are discussed below.

a. QUANTITY OF WATER. When making an advanced reconnaissance, neglect seasonal changes in water quantity unless the information is readily available from native sources. Generally it is enough to report "sufficient" or "insufficient" water. Rear-area units charged with constructing permanent installations must check the quantity more carefully. As flow gauges, meters, and related measuring devices are seldom available, quantity data is usually collected by improvised methods. When time permits, a weir (see table XXIII) can be installed which accurately measures the quantity of water flowing in a small stream. A less accurate but more rapid method is to measure the average cross-sectional area and average velocity of a stream. The accuracy of this method depends entirely on the care taken by the person making the tests.

(1) *Surface water.* (a) *Formula.* To determine the quantity of water flowing in streams, use the following formula:

$$Q = AV$$

Where:

Q = quantity of water flowing in cubic feet per minute (cfm).

A = cross-sectional area of stream in square feet.

V = average velocity in feet per minute (fpm).

To get the cross-sectional area, A , consider the stream a trapezoid and use the following formula:

$$A = \frac{1}{2} (a + b) h$$

Where:

a = width of stream at water level.

b = width of stream bed.

h = average depth of water.

As a first step in obtaining average velocity, V , measure the surface velocity, S , by checking the number of minutes required for a twig to float downstream a known number of feet. Then,

$$V = \frac{3}{4} S$$

(b) *Example.* Calculate the quantity of water in gpm from the following data:

Width of stream at water level = 7 feet.

Width of stream bed = 5 feet.

Average depth of water = 8 inches.

A twig floats downstream 16 feet in 20 seconds.

1 cubic foot = 7.5 gallons (approximately)

$$A = \frac{1}{2} (7 + 5) \frac{8}{12} = 4 \text{ sq ft.}$$

$$S = 16/20 \times 60 = 48 \text{ fpm.}$$

$$V = \frac{3}{4} \times 48 = 36 \text{ fpm.}$$

$$Q = 4 \times 36 = 144 \text{ cfm.}$$

$$Q = 144 \times 7.5 = 1,080 \text{ gpm.}$$

(2) *Ground water.* Use the stream formula to measure flow from springs. To measure the yield from wells, make a draw-down test by pumping water from the well at a known rate until the water surface in the well has stopped falling, measuring the lowering of the water surface, and recording the quantity discharged by the pump in gpm. For complete information on wells and springs, consult TM 5-296 and 5-297. Since lack of time usually prevents the use of a draw-down test on advanced reconnaissance, it is often necessary to rely on information from natives.

(3) *Municipal systems.* To determine the quantity of water immediately available from a municipal system, estimate the water stored in the reservoir or measure the flow from a convenient connection. Determination of ultimate capacity for permanent

installations involves the following factors:

- (a) Capacity of reservoir including auxiliary tanks.
- (b) Rate of reservoir refill.
- (c) Survey of distribution system including pumps and treatment equipment.

b. **QUALITY OF WATER.** Two testing kits are issued for water reconnaissance and should be used whenever available. The field water-quality-control set described and explained in paragraph 55 is a compact portable field laboratory for water testing. The kit for detecting chemical warfare agents (par. 61) is a valuable reconnaissance aid because of its compactness and the simplicity and speed of its tests.

(1) *Without test kits.* If neither kit is available, valuable information can be obtained by keen observation and common-sense judgment on the following quality characteristics:

- (a) Color.
- (b) Turbidity.
- (c) Odor.
- (d) Taste (use with caution).
- (e) Possible sources of pollution.
- (f) Condition of vegetation around source; dead or mottled vegetation may indicate the presence of chemical warfare agents.

(2) *With test kits.* When kits are available, obtain the above information and test the water for—

- (a) pH value. (See par. 61b(4).)
- (b) Chlorine demand. (See par. 61b(6).)
- (c) Chemical warfare agents, if the pH is below 6.0 or the chlorine demand greater than 5 ppm. (See par. 61.)

Note. Chlorine demand and pH value can be accurately determined without the test kits if a comparator (par. 57a) and halazone tablets (par. 41b(5)) are available.

c. **COMMUNICATIONS.** Observe condition of roads, especially around the proposed water point, and estimate their ability to withstand continued use by 2½-ton trucks under all conditions. Look for parking areas along the road near the water point. A long access road with overhead concealment is an ideal parking place. Main supply routes should be avoided whenever possible. Traffic circulation must be considered; a water point should be located on a through road.

d. **SITE CONDITIONS.** Ground reconnaissance is the best way to get accurate information on the following:

- (1) Cover and concealment.
- (2) Location of possible aerial and artillery targets.
- (3) Drainage.

- (4) Bank conditions.
- (5) Access roads.
- (6) Parking area.
- (7) Bivouac area for operators.
- (8) Work necessary to put site in operation.

148. Reports

Reconnaissance reports must be prepared carefully and delivered on time. They must be clear, complete, and concise. Report forms similar to those in figures 116, 117, and 118 are essential to insure uniformity and completeness of reconnaissance data.

a. ADVANCE RECONNAISSANCE. Advance reconnaissance reports need merely be good reconnaissance field notes. Figures 116 and 117 show a form for field notes which can be submitted as a reconnaissance report. The work estimate must include the men, equipment, and materials required to put the water point in operation. If time permits, an estimate of the work necessary to develop the point is included.

b. HIGHER ECHELON RECONNAISSANCE. Higher echelon water reconnaissance reports must be detailed as they become part of engineer planning data. A recommended report form is given in figure 118.

c. CHECK LIST FOR WATER RECONNAISSANCE. Information on the following items must be obtained and recorded:

- (1) *Quantity available.*
- (2) *Quality.* (a) Color.
- (b) Odor.
- (c) Turbidity.
- (d) Taste.
- (e) Possible sources of pollution.
- (f) Condition of vegetation.
- (g) pH value.
- (h) Chlorine demand.
- (i) Tests for chemical warfare agents.
- (3) *Communications.* (a) Condition of roads.
- (b) Extent of road net.
- (c) Traffic circulation.
- (4) *Site conditions.*
- (a) Cover and concealment.
- (b) Possible aerial and artillery targets.
- (c) Drainage.
- (d) Bank conditions.
- (e) Access roads and parking area.
- (f) Bivouac area for operators.
- (5) *Work estimate.*

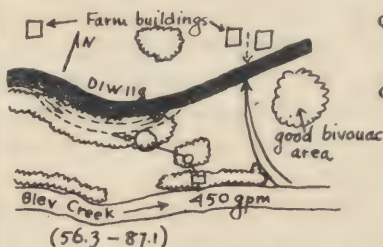
ENGINEER RECONNAISSANCE REPORT

File No. _____ Page 1 of 1
 Report No. _____ Party leader Smith 1st LT Hqs S Co
 (Name) (Grade) (Organization)

 (Place) (Hour and date)
 Maps France and Belgium; 1944; 1:62,500
 Deliver to Engr. Bn Hq St Nicholas 1100 7 Oct
 (Organization) (Place) (Hour and date)

Additional Remarks and Sketch

| Key | Object | Time Observed | Work Estimate? |
|-----|--------|---------------|----------------|
| ① | (W) | 0835 | Yes |



Quantity: $A = 257 \text{ ft}$
 $V = 30 \text{ fpm}$
 $Q = 60 \text{ cfm or } 450 \text{ gpm}$
 Quality: slight turbidity
 no odor
 possible pollution from nearby farms
 $\text{pH} = 6.8$
 chlorine demand = 2 ppm

Communications: hwy road with good drainage runs to 1st Infantry area. Not used for division supplies. Turnout at w/p must be constructed.

Site Conditions: good concealment
 no targets in vicinity
 ground slopes gently from road to stream - good drainage.
 banks - 3 ft high: sodded
 Use access road as parking area
 Grove of trees or farm house can be used as bivouac for w.p. personnel.

Rating: Excellent w/p for 1st Inf

Smith

(Signature)

1st LT Hqs

(Rank) (Organization)

(ENGINEER WORK ESTIMATE ON OTHER SIDE)

Figure 116. Recommended form for field notes with sample report of advanced water reconnaissance, first page.

10. DESCRIPTION AND STATUS OF PROPOSED IMPROVEMENTS (IF ANY).
CIPAL SYSTEM, INCLUDE SOURCE)

11. WORK ESTIMATE

PER IMMEDIATE OPERATION

TAXES

MATERIALS

ESTIMATED

MATERIAL

FOR DETAILS

7. SITE CONDITIONS (CONTD)
DRAINAGE.....
WATER (IF STORAGE SOURCE).....
DISTRIBUTION FACILITIES (EXISTING).....
8. SECTION OF AREA (SHOW ROAD MAP AND TRAFFIC CIRCULATION)

9. SECTION OF WATER POINT (SHOW POINT SET UP FOR IMMEDIATE OPERATION IF WATER POINT IS A MINORITY SYSTEM. INCLUDE SECTION OF FIELD)

WATER RECONNAISSANCE REPORT

FILE NO. ... REPORT NO. ... PAGE ... OF ...

REPORTED BY (NAME) (ORGANIZATION) DATE

FORWARDED TO (NAME) (ORGANIZATION)

1. LOCATION OF WATER SOURCE

MAP COORDINATES.....

2. TYPE OF SOURCE (CHECK ONE) STREAM, LAKE, POND, SPRING, WELL, RESERVOIR, OTHER

LOCAL MAP OF WATER

3. DATE AND HOUR OBSERVED

4. FIELD NOTES

5. QUALITY

6. COMMENTS: REFERENCE TO COMMENTS

7. SITE CONDITIONS (IF MINORITY SYSTEM, USE ITEMS 9 AND 10)

8. COMMENTS

9. COMMENTS

10. COMMENTS

11. COMMENTS

12. COMMENTS

13. COMMENTS

14. COMMENTS

15. COMMENTS

16. COMMENTS

17. COMMENTS

18. COMMENTS

19. COMMENTS

20. COMMENTS

FIRST, SECOND, AND THIRD PAGES OF RECOMMENDED WATER RECONNAISSANCE REPORT FORM FOR HIGHER ECHELONS

Figure 118. Recommended water reconnaissance report form for higher echelons. (1) First page. (2) Second page. (3) Third page.

Section II. DEVELOPMENT OF WATER SOURCES

149. General

a. SCOPE. Development of a water source consists of any work which increases the quantity and improves the quality of the water or makes it more readily available for treatment. Development of the following types of sources are considered in this section:

- (1) Surface water.
- (2) Wells.
- (3) Springs.
- (4) Sea water.
- (5) Municipal systems.
- (6) Rain water.

b. ORDER OF DEVELOPMENT. Usually, surface-water sources are most easily developed in the field. If no suitable surface source can be found, a ground-water source should be developed by constructing a new well or improving an old one. Wells generally yield water of higher quality than surface sources, but the work of developing them must be balanced against the ease of getting water from surface sources. In populated areas, municipal systems should be used unless damaged beyond repair. Sea-water sources can be used when other sources fail to provide enough water, but their use requires distillation equipment.

c. PRECAUTIONS. (1) Avoid elaborate developments; simplicity brings quicker results. Before converting a temporary water source into a permanent one, reconnoiter the area for a source requiring less development.

(2) Equip all intake hoses or pipes with an intake strainer regardless of the clarity of the water source.

150. Surface-Water Sources

Water at the intake point from which surface water is drawn should be as clear and deep as possible. On streams, this point must be upstream of bathing and animal-watering facilities. The intake strainer should not rest on the bottom or be suspended so near the surface that air and floating matter are drawn into the suction pipe. Where no unusual conditions exist, the intake strainer is merely placed on a rock in water at least 6 inches deep. If the stream bottom is silty, the screen may be placed in a sunken bucket or hung from a stake. When satisfactory results cannot be obtained by using these simpler methods, one of the intakes discussed below should be used.

a. PITS. Pits should be dug in streams so shallow that the in-

take screen is not covered by at least 4 inches of water. The screen is laid on a rock or board placed on the bottom of the pit. Pits dug in streams with clay or silt bottoms should be lined with gravel to prevent dirt entering the purification equipment. The screen is placed on a layer of gravel and then the pit is filled with gravel. (See fig. 119.) The gravel acts as a coarse strainer and shields the screen from damage by large floating objects.

b. DAMS. Small streams can be dammed to raise the level of the water enough to cover the intake strainer or to impound the water. (See fig. 120.) In swift streams where floating debris would damage the intake strainer, a wing or baffle dam can be constructed which protects the intake without impounding the stream. (See fig. 121.)

c. FLOATS. In large streams where the quality of water varies across its width or where the water is not deep enough near the banks to cover the intake strainer, the position of the strainer can be controlled from anchored floats. Floats can be made of logs, lumber, sealed cans, or empty fuel drums. (See figs. 122 and 134.) The principal advantage of a float intake is the ease with which the screen can be adjusted vertically.

d. GALLERIES. Water from muddy streams can be improved by digging intake galleries along the bank. A trench is dug along the bank deep enough so water from the stream percolates into it or so it intercepts ground water flowing toward the stream. The trench is filled with gravel to prevent the sides from collapsing and the intake screen is placed in the gravel below the water level. A properly prepared gallery (fig. 123) justifies the work of con-

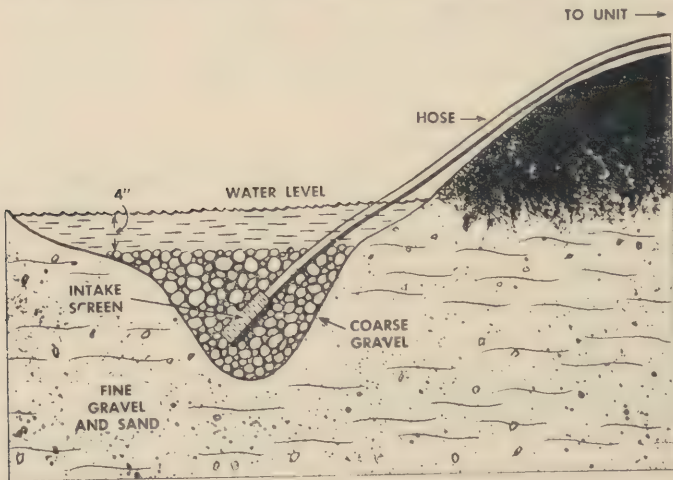


Figure 119. Surface intake buried in gravel-filled pit. Gravel acts as coarse strainer.

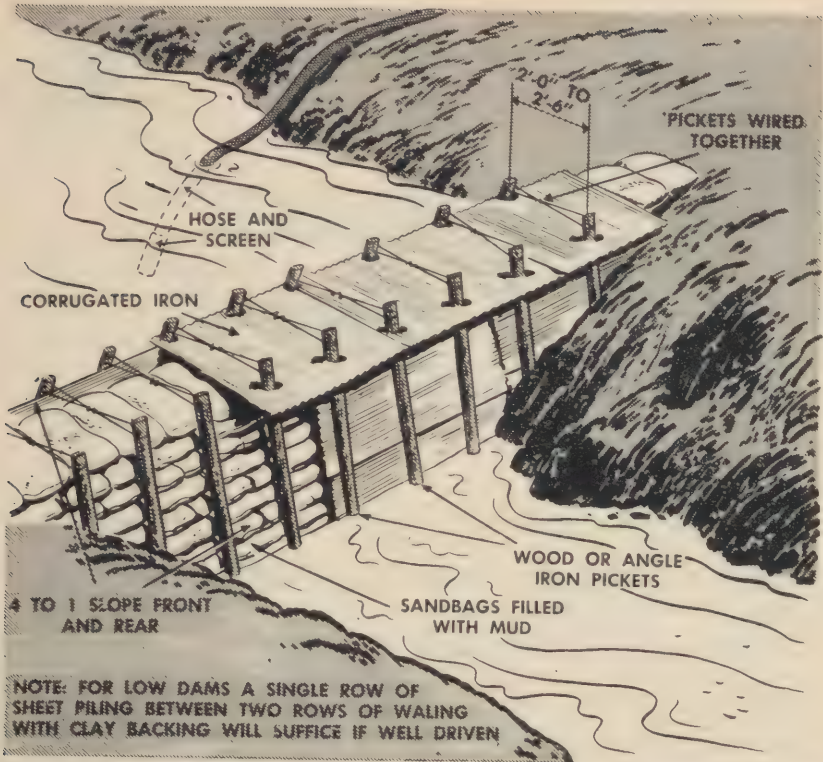


Figure 120. Improvised dam constructed of sandbags, corrugated metal, pickets, and wire for impounding small streams.

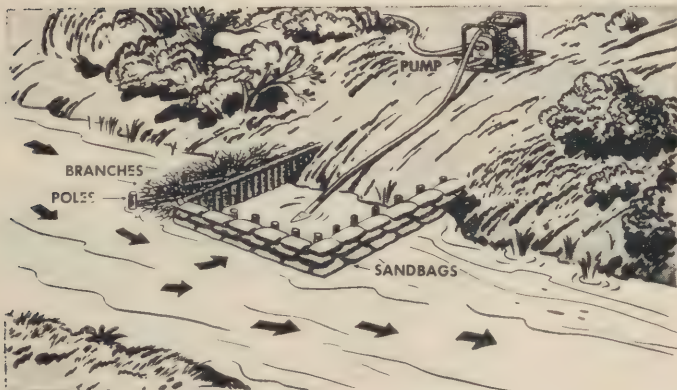


Figure 121. Baffle dam for protecting the intake strainer from debris in swift streams.

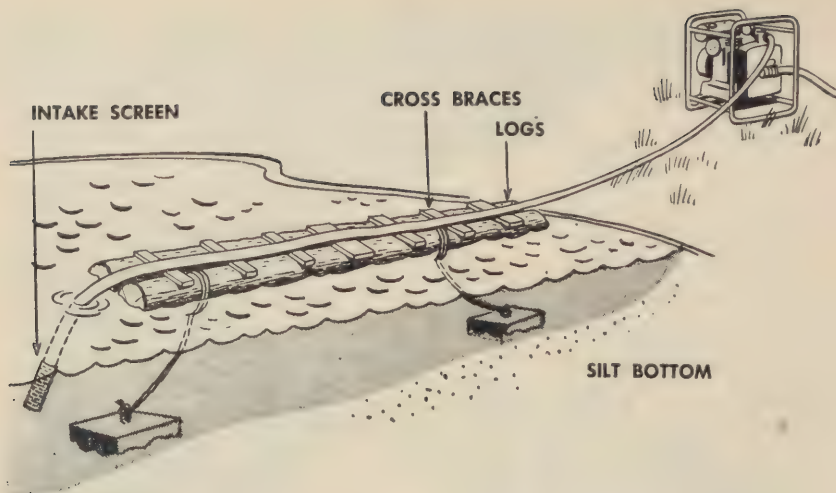


Figure 122. Float-type surface intake constructed of logs.

struction by reducing the amount of coagulating chemicals needed and by eliminating frequent backwashing of the filter.

e. **WELLS ALONG STREAM BANKS.** Wells along stream banks sometimes yield water so much higher in quality than the stream water that the extra work of installing them is justified. Directions for installing a driven well (fig. 124) are found in TM 5-297.

f. **STREAM-BED DAMS.** Dry stream beds can be developed into water sources by constructing subsurface dams which stop the flow of ground water. Conditions required for successful use of such dams are a stream bed of sand or gravel lying on a subsurface layer of impervious material which extends upward into the banks. A dam sunk to the impervious subsurface layer of such a stream impounds the ground water as shown in figure 125. Dams can be constructed of wood, concrete, or sheet piling. Recovery of

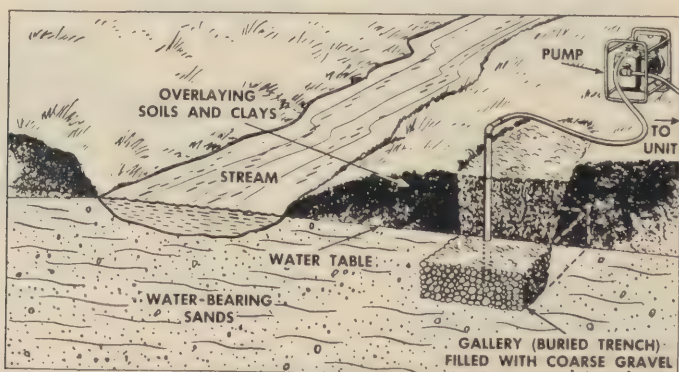


Figure 123. Gravel-filled gallery intake installed on bank of muddy stream.

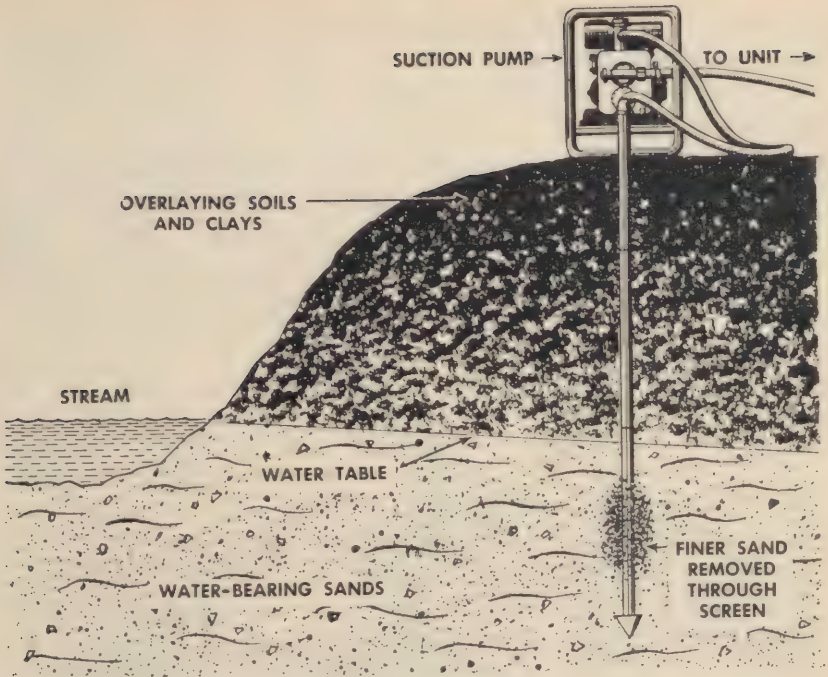


Figure 124. Drive-point well installed on bank of muddy stream.

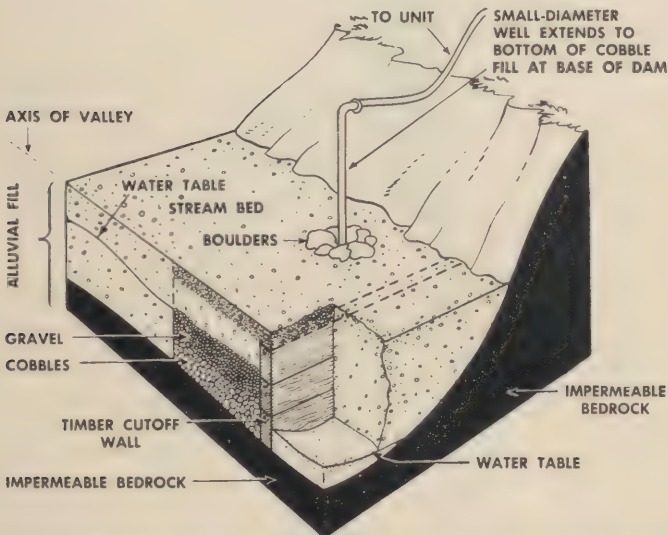


Figure 125. Subsurface dam installed in dry stream bed to impound ground-water flow. This device is effective in stream beds of sand or gravel lying on a subsurface layer of impervious material which extends upward into the banks. Dam is made of logs resting in the impervious subsurface layer.

the impounded ground water can be made easier by building a gallery back of the dam.

151. Wells

A well is a water source with an intake which penetrates to the ground-water level. Wells are classified according to methods of construction such as dug, bored, jetted, driven, or drilled. (See TM 5-297.) One simple way to increase output of existing wells is to substitute larger pumps for smaller ones. Other specific

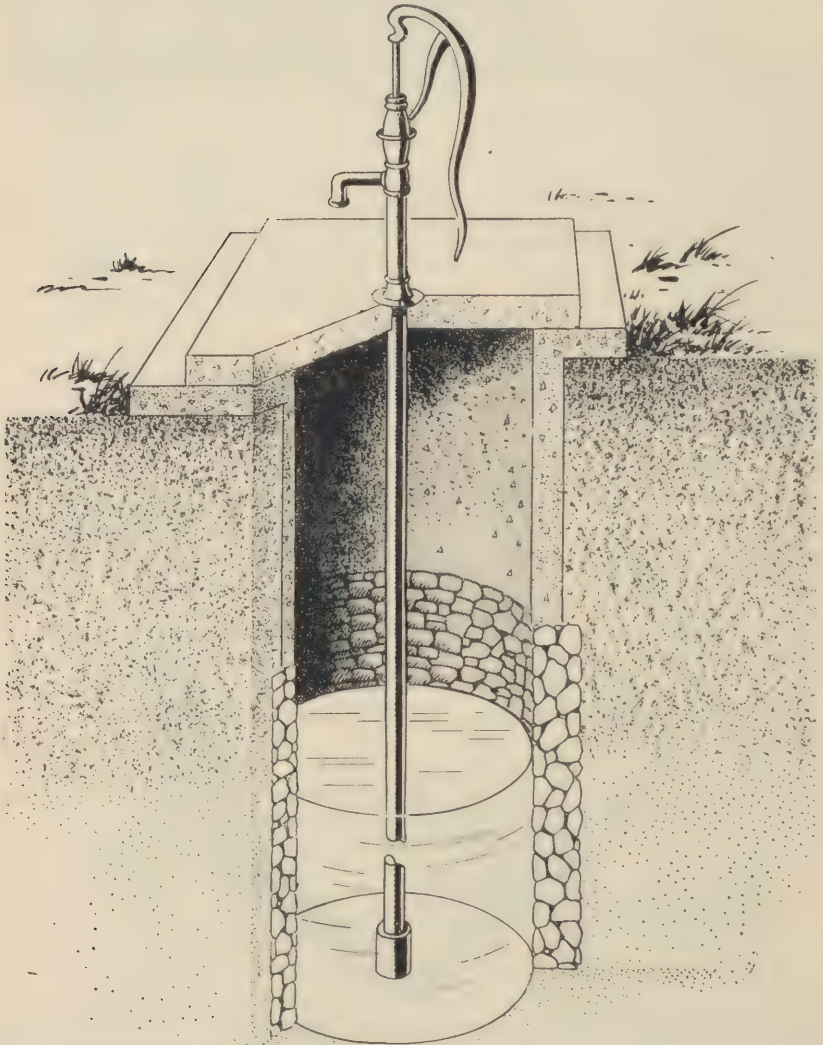


Figure 126. Cross section through typical dug well.

means of improving the quantity and quality of water from existing wells are discussed below.

a. CLEANING. In time, all wells tend to become clogged with sand, but dug wells must be cleaned more often than other types because of their larger opening. (See fig. 126.) Dug wells should be cleaned before being used by lowering a man into the well to shovel the accumulated dirt and debris into buckets, which are raised and emptied. Small-bore wells can be cleaned by backwashing (*e* below) or acid-washing (*g* below).

b. INCREASING DIAMETER. Wells can be increased in diameter, but the increased yield is not proportionate to the increased size. Dug and bored wells are usually enlarged manually with hand tools. Driven, jetted, and drilled wells require special equipment to expand their diameters. Generally, it is easier to drill a new well than to increase the diameter of an existing deep well.

c. DEEPENING. Deepening an existing well increases the yield, if the original bottom does not already extend to the bottom of the water-bearing formation. Deepening is especially helpful with shallow wells which run dry when pumped, because the permissible draw-down or hydraulic gradient is increased. (See fig. 127.) The yield from deep wells may increase with deepening, if a more productive water-bearing formation is tapped.

d. IMPROVING CASINGS. Wells may be cased to prevent collapse of well walls and contamination by surface drainage. Casings should extend at least 1 foot above the level of the ground. The space between the casing and pump pipe and the space between the outside of the casing and the well wall must be tightly sealed. The casing must have no cracks or holes. Open dug wells should be provided with a watertight cover, preferably of concrete. The quality of water from deep wells can often be improved by using cement-grout casings to exclude undesirable subsurface waters. (See TM 5-297.)

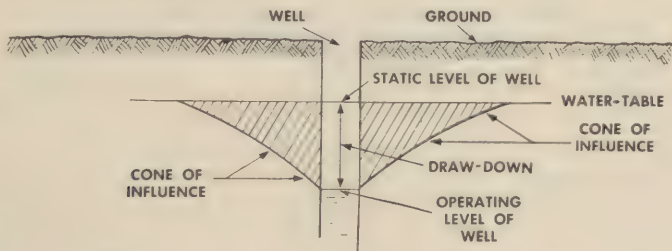


Figure 127. Draw-down and cone of influence caused by pumping water from a well. Draw-down is the distance between the water table and the operating level when well is being pumped. The cone of influence is the conical depression in the ground-water table caused by water flowing into the well.

e. **OVERPUMPING AND BACKWASHING.** (1) Overpumping and backwashing are related methods used to increase ground-water flow into wells by increasing the porosity of the water-bearing sand formation. They are used principally for deep wells, but may be helpful for cleaning shallow wells.

(2) Overpumping consists of pumping water from a well faster than the normal yield until the draw-down becomes constant or the well runs dry. This causes a rapid flow in the water-bearing formation, moving the fine sand near the screen into the well and leaving voids in the coarser sands and gravel. As the operation continues, fine sand farther from the screen may bridge the openings or voids in the coarser-grained material. This bridging can be prevented by backwashing or reversing the flow through the water-bearing formation. Alternately starting and stopping the pump is one easy and effective method of backwashing. (See TM 5-297 for other methods.)

f. **GRAVEL PACKING.** When a water-bearing formation contains no coarse-grained material, gravel can be packed around the well screen to increase the yield of small-bore wells. Gravel packing is most valuable in obtaining water from formations containing silt and clay or formations composed of fine sand of equal grain size. It is difficult to add gravel to an existing well without redrilling. The usual method consists of removing the screen, pumping out the sand through an inner casing, and simultaneously feeding in gravel between an outer and inner casing. (For further details, see TM 5-297.)

g. **ENCRUSTED SCREENS.** (1) Iron or calcium carbonate encrustations on brass, bronze, or stainless-steel well screens can be removed by treating them with muriatic or sulfuric acid. (See par.

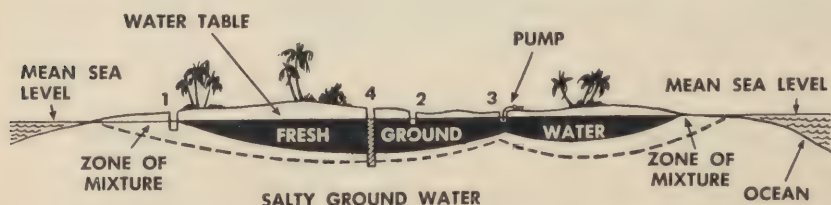
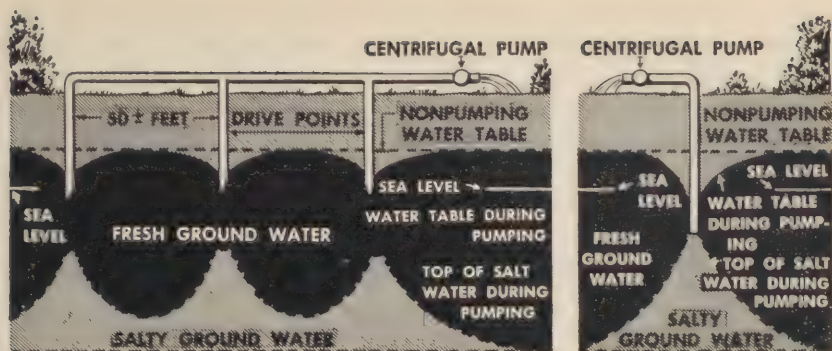


Figure 128. Diagram of lens of fresh ground water on small island composed of pervious materials. Fresh ground-water layer from local precipitation floats in hydrostatic equilibrium on salty ground water, with a narrow intervening zone of brackish ground water (zone of mixture). Shallow wells near shore (well 1) may encounter brackish water; wells in central part of island (wells 2 and 3) will yield potable water. On very small islands, fresh ground water may be unobtainable. Note that the rise of salt water (up-draw) under a well during pumping (well 3) is many times the draw-down of the water table. Well 4 is too deep and will yield salty water. Vertical scale of diagram is about twice the horizontal scale.



① *Battery of driven wells to spread pumpage and decrease draw-down, thereby minimizing danger of salt water up-draw. Well screens must be below water level so suction is not lost during pumping. Wells should be about 50 feet apart and should not extend more than 1 or 2 feet below sea level. Diagram is not to scale. Zone of mixture is not shown.*

② *Contamination of a well caused by excessive pumping. If well is too deep, contamination is more likely to occur than if well is shallow. Wells that have become contaminated may freshen if allowed to rest. Diagram is not to scale.*

Figure 129.

34c(2).) A 10 to 25 percent solution is formed by adding acid to the water through a separate pipe. The pipe is lowered into the well until it is just above the screen and the acid is poured or pumped in. The pipe is removed and the acid is left in the well 2 to 5 hours, depending on the concentration needed. Water is then pumped from the well until its pH value is the same as it was before the acid treatment.

(2) As a precaution during the acid treatment, a solution of sodium bicarbonate should be kept at hand to neutralize acid spilled on the hands, clothing, or the pump. The pipe used to add the acid should be sprayed with water as it is removed.

h. EXPLOSIVES. In deep wells which tap ground water in porous rock, explosives can be used to shatter the rock and produce a larger draining area. Explosives are most effective in hard, brittle rocks, such as limestone, and least effective in soft, tough shales. Relatively small charges should be placed and tamped opposite the strata to be opened. Sand packed around the screen of wells tapping water-bearing sand can be jarred loose and dislodged by exploding blasting caps inside the screen at 2-foot vertical intervals.

i. MULTIPLE WELL POINTS. Wells which tap the same water-bearing formation and are connected to the same pump are called "multiple well points." This method is used to increase the quantity of water flowing to a large pump when the yield from a single

fully developed well is insufficient. A disadvantage of this system in normal situations is the overlapping of the cones of influence of the individual well points, causing excessive draw-down in all wells. On small islands of pervious material, such as coral or sand, this relationship between the draw-down of multiple well points causes them to act like a gallery and prevents the undesirable up-draw of the salty ground water which underlies the layer (lens) of fresh ground water. (See figs. 128 and 129.)

152. Springs

Springs appear when ground water escapes to the surface. (See fig. 130.) The principles governing their formation are covered in TM-296. Specific problems in spring development are discussed below.

a. CLEANING. All springs must be cleaned by removing debris, undergrowth, top soil, loose rocks, and sand in the immediate vicinity. When the spring is on a hillside, all possible sources of contamination from surface drainage should be eliminated above the spring. Future contamination should be prevented by fencing off the area and by constructing earth dikes in the form of an inverted V which straddle the spring and divert flow from it. Swampy areas surrounding springs on level ground should be drained.

b. COLLECTING BASINS AND BOXES. Water from small hillside springs can be collected in boxes. These boxes may vary from simple tarpaulin-lined holes to concrete reservoirs, depending on the time and material available. A cone-shaped hole should be dug around springs on level ground to collect the water. The hole may be lined with concrete. All springs and collecting basins must be covered to prevent contamination. Unless the sides of the basin extend well above the surrounding ground, the spring water becomes polluted by surface wash and requires careful treatment before use. The overflow pipe of spring boxes should be high enough above the ground level to prevent surface waters entering the box. The pipe should be screened to prevent the entrance of insects and small animals. Covered concrete spring boxes are the surest means of preventing pollution. Springs in hard consolidated rock, called "large-fracture springs," emerge as thin sheets of water. Little can be done to increase the flow at any one point, but for small springs a collecting box can be constructed and sealed to the underlying rock.

c. COLLECTING TRENCHES. In some localities, it is possible to dig trenches to collect the flow from large springs and lead the water to a reservoir. An impervious lining for the trench elim-

inates loss of water through seepage and prevents turbidity. It is not advisable to attempt to develop large-fracture springs by explosives. Blasting opens new fractures which may divert the water entirely away from the spring.

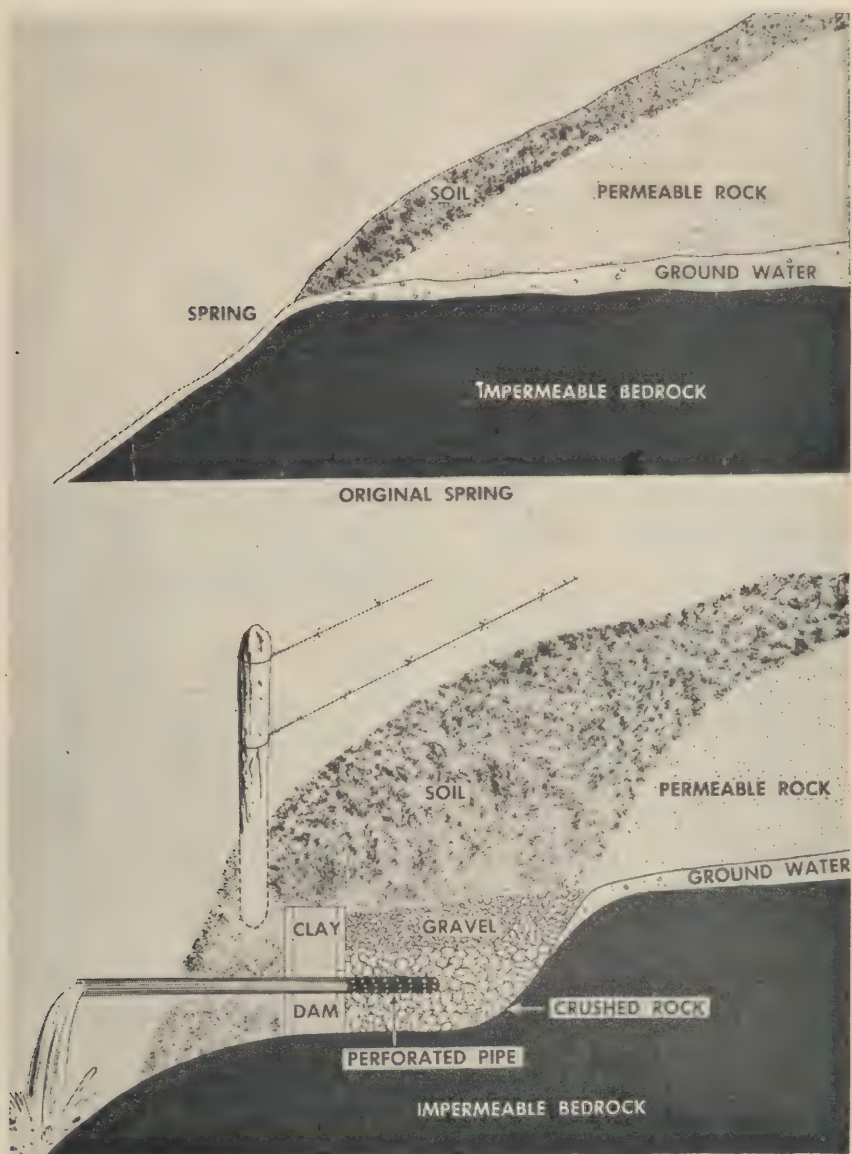


Figure 130. Simple method of improving flow from spring by tunneling uphill to water-bearing formation. Equipment required includes pipes, wood or concrete for dam, and fencing. Dam must be watertight. Restricted zone to protect spring from contamination is established by draining and fencing hill 100 feet above spring.

d. TUNNELING. If the spring is on a steep slope of loose rock or sand, the flow of water can be increased by constructing tunnels leading uphill from the point of emergence to the water-bearing formation. The tunnels can be filled with coarse gravel or rocks to prevent caving. The flow from these tunnels can sometimes be concentrated by constructing a dam at their outlet and draining the impounded water through a pipe. (See fig. 130.)

e. PRECAUTIONS. (1) Digging is a more economical and more positive method of spring development than blasting.

(2) All ditches, basins, boxes, and outlets should be covered to prevent surface contamination and to retard evaporation.

(3) Pipe or hose should be used to conduct the water to the point of use.

(4) Nearby surface sources of contamination should be investigated and eliminated.

153. Sea-water Sources

A sea-water source is a type of surface source affected by certain special factors, such as rise and fall of the water level caused by tide, destructive action of the surf, corrosiveness of salt water, suspended sand and silt in the water, surface oil along beaches,

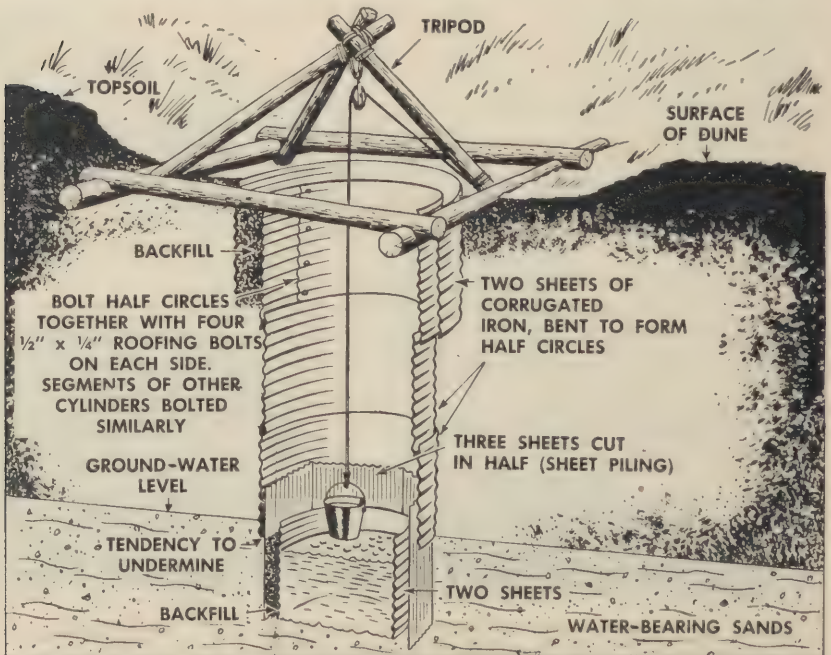


Figure 131. Well dug in beach sand to tap lens of fresh ground water lying on salty ground water. Well is cased with metal culvert piping.

and the many living organisms in the ocean. Where distillation equipment can be located on sheltered bays, harbors, estuaries, or lagoons, salt-water intakes can be constructed the same way as fresh-water surface intakes. (See par. 150.) Generally, however, sea water is distilled on small islands where there is not enough fresh surface and ground water to supply the troops and where the equipment must be located on or near open beaches. Under these conditions, the two types of salt-water intakes discussed below are satisfactory if properly installed.

a. **SALT-WATER WELLS.** Along shallow, sandy beaches wells are easily dug which tap fresh or salty ground water. When provided with a suitable casing (figs. 131 and 132) these wells eliminate the problems caused by tides, surf, and shallow water close to shore. Whenever possible, beach wells should be used in preference to offshore intakes, because they can be constructed back of the beach line under natural overhead concealment. Wells can also be driven or jetted. (See TM 5-297.)

b. **OFFSHORE INTAKES.** If lack of time, men, and equipment, or



Figure 132. Top of the beach well shown in figure 131 during construction.

rocky coral beaches prohibit constructing beach wells, offshore intakes must be used. To prevent excessive wear on distilling equipment caused by sand, oil, or organic materials, the intake screen must be located in deep water outside the surf, and must be positioned vertically so it does not suck air and yet remains off the sea bottom at low tide. A satisfactory offshore salt-water intake can be constructed with the following items:

(1) *Rigid pipe.* A rigid pipe on anchored timber supports can be used to carry the intake strainer beyond the surf to deep water. The pipe must be securely anchored in position and protected from wave-tossed debris by piling or riprap. Figure 133 shows the rigid-pipe end of an offshore intake before riprap has been added.

(2) *Intake floats.* Beyond the surf line, the intake strainer can be suspended from floats constructed of old fuel drums or other buoyant materials. Floats must be anchored against the action of onshore winds and waves. Rubber suction hose issued to distillation units can be used to connect the rigid pipe lying on the sea bottom to the pipe carried on the floats. A sketch of a float made from oil drums is shown in figure 134.

154. Municipal Sources

The water supply system of a modern municipality usually consists of a developed water source, pumping, filtering, and treating equipment, distributing reservoirs, and mains and submains. The developed water source may be a river, well, spring, or an im-



Figure 133. Shore end of offshore salt water intake. Rigid pipe fastened to stakes should be covered with riprap at permanent installation.

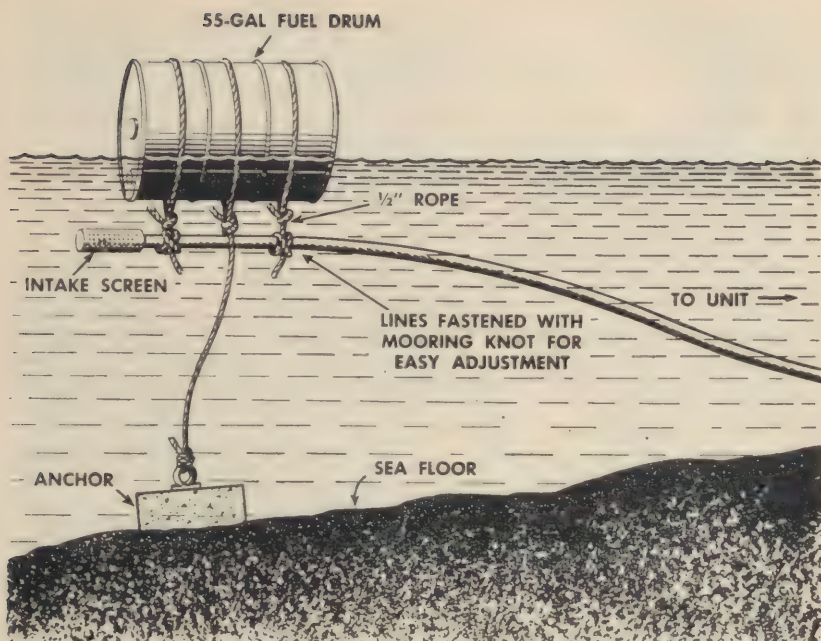


Figure 134. Float-type sea-water intake made from empty fuel drums. Floats must be securely anchored. Strainer must be located so it is off bottom at low tide.

pounding reservoir. Except for rivers, these sources are easily contaminated by a retreating enemy and should be carefully tested for poisons before using. Water intakes for field water purification equipment can be located at any of the points discussed below. In all cases, the water distributed to troops must meet the residual chlorine standards specified in paragraph 41.

a. MUNICIPAL WATER SOURCES. The developed source of a municipal water system can be used as a military water point even though the system is damaged by military action causing contamination and pollution in the distributing systems. Methods of developing a water intake from this source are the same as for any field source discussed in this section.

b. SURGE TANKS AND STANDPIPES. Surge tanks and standpipes are two types of small, intermediate distributing reservoirs. They are tall, vertical tanks usually located on high ground, near or within the community which they serve. Elevated tanks are used in level country. When these reservoirs are used as water sources, the most convenient connection is the main-valve bypass in the valve house. (See fig. 135.)

c. HYDRANTS. Within a community, hydrants are good intake

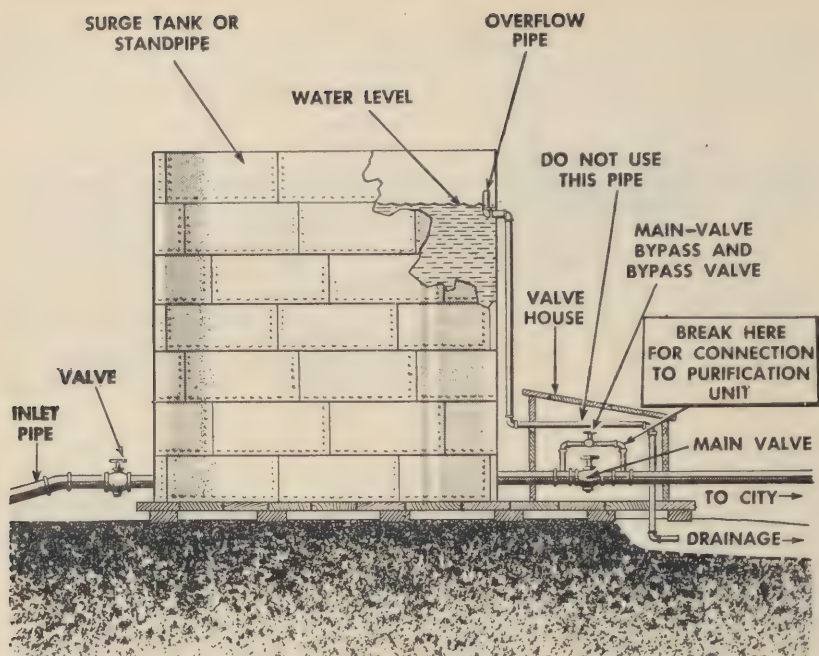


Figure 135. Surge tank with valve house. Best location for intake is main-valve bypass.

points. (See fig. 136.) Before a field water purification unit can be connected directly to a hydrant, a pipe adapter must be made. These adapters can be fabricated with the tools and equipment in the blacksmith and the pipefitting sets. Where the pressure in the mains is low or fluctuates greatly or where the water is turbid, it is better to run the water from the hydrant into a sedimentation tank rather than to use a direct connection.

d. FOUNTAINS AND PUBLIC FACILITIES. Fountains, water troughs (fig. 137), and artificial ponds may be used as expedient water sources for small purification units. However, they furnish a limited supply which may be contaminated.

e. INTERIOR CONNECTIONS. Connections inside private dwellings of modern communities are valueless as a source of water for purification equipment because of the limited quantity available. If they are used in an emergency, the water must be carefully disinfected by chlorination unless it is tested and declared safe by the Medical Department.

f. MAINS. Distributing mains yield large quantities of water even after flow into them has stopped. Water stored in mains can be recovered by tapping a low point in the distributing system, but special equipment is required to make the connection. Water re-

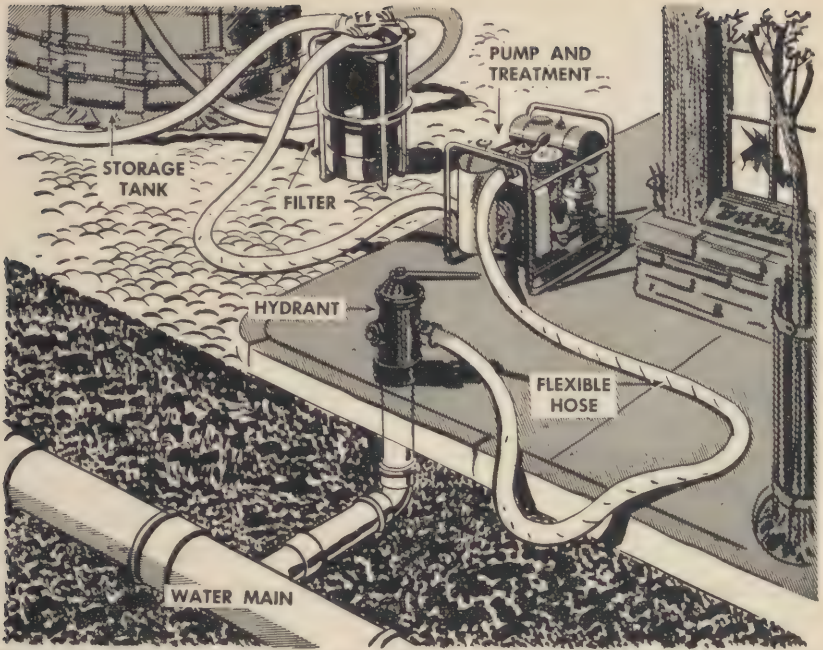


Figure 136. Hydrant used as source of water for portable purification unit. When pressure is low or water is turbid, a sedimentation tank should be placed between hydrant and unit.



Figure 137. Fountain and watering trough being used as water source for a portable purification unit set up in a small public square in Italy. Lay-out of equipment is the same as shown in figure 153.

covered from mains must be carefully treated for possible contamination from adjacent sewers.

g. SOURCES OF CONTAMINATION OR POLLUTION. When a municipal water supply system is used for military purposes, the water must be tested regularly for contamination and pollution, especially when the municipality is subject to enemy action. Likely sources of contamination or pollution are listed below.

(1) *Poisoned source.* Raw water stored in reservoirs, galleries, wells, or tank may be made unfit for large-scale treatment by the introduction of chemical poisons.

(2) *Inadequate treatment.* Few municipal water systems are designed to supply enough water to meet both civilian and military needs. Overloading the treatment plant results in inadequate filtration and disinfection. Water that is apparently safe for civilian consumption is never safe for troops unless it meets Army standards. The treatment plant must be carefully surveyed to assure proper treatment of the water.

(3) *Improper distributing reservoirs.* Water may become contaminated after treatment and before it enters the distributing mains, if the distributing reservoirs or the clearwell of the filter plant are not safeguarded. These points must be checked for contamination from surface wash and ground-water drainage.

(4) *Broken mains.* Since sewer and water mains run parallel in many cities, breaks in these mains will contaminate the water system. All breaks should be repaired and the mains disinfected by chlorination. (See table XIX for dosage.)

(5) *Cross connections.* (a) A cross connection is an improper arrangement of pipes which permits impure water to mix with and contaminate or pollute the public water supply. Cross connections are generally found in buildings served by two water systems, such as chemical and other manufacturing plants which have a public water supply and a private supply of untreated cooling water, both piped to the same process equipment and separated from each other by unreliable gate valves. Cross connections are also found in laundries and similar industries, where safe water is polluted by use and returned to the public water supply by improper drainage connections.

(b) The enemy can deliberately poison a municipal water supply by forcing chemicals into the distributing mains with a high-pressure pump piped to a service connection within a building.

(6) *Back-siphonage.* (a) Back-siphonage is a type of cross connection caused by improper design of plumbing fixtures or piping. It is most frequently found in cities using modern sewerage systems and flush-type toilet fixtures. It is caused by—

1. Flushometer valves installed without vacuum breaks.
2. Submerged float valves.
3. Submerged and inverted supply pipe in plumbing fixtures and industrial processing tanks.

(b) Backflow of contaminated or polluted water from tanks, vats, and plumbing fixtures is caused by a loss of pressure in municipal supply lines, which is very probable during military action.

155. Rain Water

In regions of heavy rainfall and rapid surface run-off, such as small tropical islands, rain water is the principal water source for the natives. A 24- by 50-foot collecting surface in an area with 54 inches annual rainfall collects approximately 40,000 gallons of water. Collecting surfaces may be constructed of tarpaulins supported on wood, of metal, or of concrete, but they must be elevated enough so the water drains into covered tanks. These surfaces are subject to contamination and every effort should be made to keep them clean. Tents can be used as collecting surfaces by equipping them with wooden or metal roof gutters. (See TM 5-280 for details.)

Section III. DEVELOPMENT OF WATER POINTS

156. General

a. DEFINITION. Development of a water point is the gradual improvement of the point to increase the efficiency of water-treating and distributing facilities.

b. SCOPE. This section covers the aims of water-point development and methods of improving foundations, storage facilities, communications, standpipes and pipe lines, dry points, and camouflage.

Note. Development of intakes is described in section II, and lay-out of equipment in section IV, this chapter.

157. Aims of Development

a. Six aims measure the value of all work done on water-point development. Unless the work furthers one of these aims, it is unnecessary and should not be done. Those aims are to—

- (1) Increase the quantity of potable water available.
- (2) Improve the quality of the water produced.
- (3) Lessen distribution problems.
- (4) Decrease maintenance.

(5) Improve security.

(6) Improve living conditions of water point personnel.

b. PLANNING. Orderly development must be carefully planned. Before selecting a water point that requires extensive development, the area should be reconnoitered for a site requiring fewer improvements. If such a site cannot be found, recommended improvements should be listed and a time schedule prepared for the project. All recommendations should be checked to insure that each item increases the efficiency of the water point. In planning improvements, work should be directed toward breaking bottlenecks by improving limiting operations first.

c. CHECK LIST FOR WATER POINTS. The following list of questions is helpful in planning developments.

(1) Has the area been reconnoitered for a point requiring fewer improvements? (See par. 147.)

(2) Does the source yield enough clear water? (See pars. 150 through 154.)

(3) Are all spillage areas, especially the loading area, well-drained? (See par. 160.)

(4) Are all tanks and equipment level and off the ground? (See par. 160.)

(5) Are there enough storage tanks to handle peak loads? (See par. 161.)

(6) Can the treated water be safely and quickly distributed? (See pars. 162 and 163.)

(7) Will dry points eliminate distribution problems? (See par. 164.)

(8) Should a pipe line be used? (See par. 163.)

(9) Is the water point well camouflaged? (See par. 165 and fig. 161.)

(10) Is the treatment-equipment lay-out correct? (See pars. 166 through 170.)

(11) Are the water-point records adequate? (See pars. 171 through 174.)

158. Extent of Development

The extent to which a water point is developed depends primarily on the time, labor, and material available. At front-line installations, development is the minimum consistent with supplying enough potable water to the troops. A typical front-line water point is shown in figure 138. In rear areas, however, the extent of development varies with the size of the water point, the problems to be overcome, and the permanency of the installation.

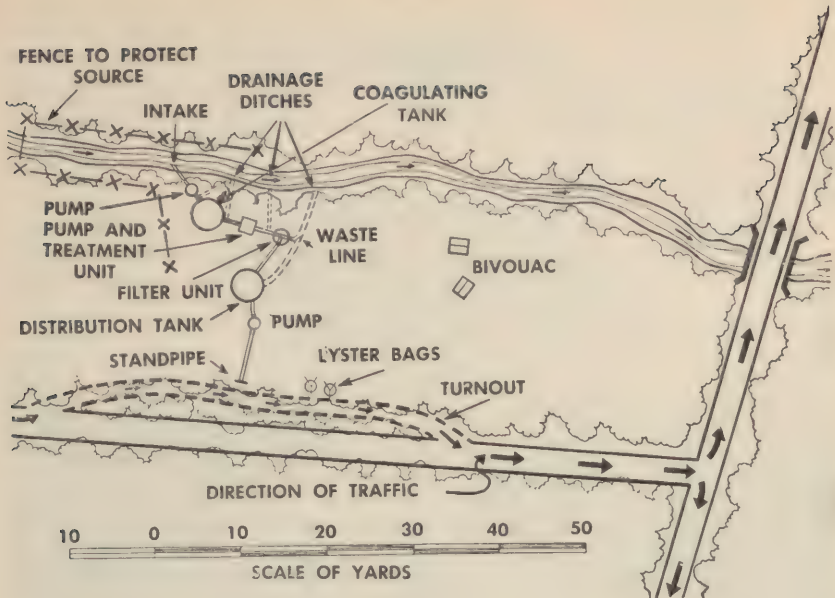


Figure 138. Typical front-line water point.

159. Order of Development

a. The order in which improvements are made is determined by the relative importance of the problems encountered at each site and by the tactical situation. In jungle terrain, where water is readily available but roads are few and snipers plentiful, distribution facilities and security are considered first. This is shown by this development schedule for an actual forward water point on an island in the Southwest Pacific.

- | | |
|----------|--|
| 1st day: | Equipment installed and water distributed. Source cleared of vegetation and debris. Drainage ditches dug. |
| 2d day: | Bulldozers make turn-around. Erection of traffic signs completed. |
| 3d day: | Two more canvas storage tanks erected. Construction of pipe line to division service area started. |
| 4th day: | Elevated platform for 3,000-gallon storage tank installed under enemy fire so water can be dispersed at night when equipment is moved to rear. |
| 5th day: | Revetments installed around equipment for protection against sniper fire. |
| 6th day: | Eight-mile pipe line completed. |
| 7th day: | Bulldozer cuts new one-way road to point. |

10th day: Portable equipment moved to new forward site; point taken over by corps engineers.

b. Note that most of the development requires using troops and equipment not organically assigned to water purification units.

160. Supports and Platforms

a. DRAINAGE. Waste water from filters, leakage from tanks, and spillage from distributing facilities keep water points continually wet. Unless ditches are cut to drain the area, the point may become unworkable. (See fig. 139 and FM 5-10.)



Figure 139. Mud caused by lack of drainage at water point in Italy.

b. PLATFORMS. To prevent canvas tanks rotting, they must be kept off the ground so air can circulate under them.

(1) *Low platforms.* At forward water points, tanks are normally erected on platforms resting on the ground. (See fig. 140.) These platforms can be knocked down and transported in the same truck with the purification equipment. When dimensioned lumber is not available, satisfactory platforms can be made from saplings if branches are trimmed flush with the trunk.

(2) *Elevated platforms.* If potable-water storage tanks are erected on elevated platforms, distribution can be improved by

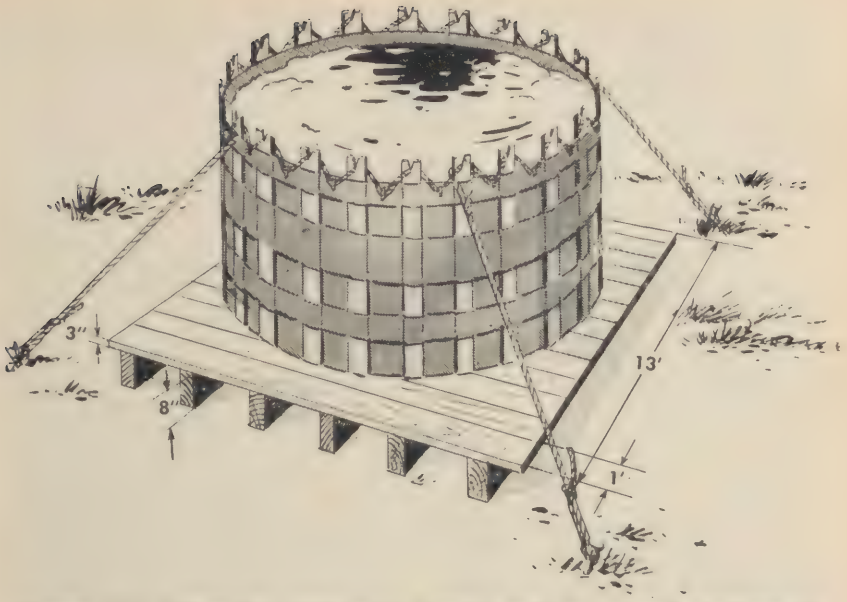


Figure 140. Three-thousand-gallon canvas tank on ground platform of dimensioned lumber.

using gravity feed to standpipes and distributing nozzles. Construction details for an elevated platform of dimensioned lumber are given in figure 141. A view of this platform being used in a theater of operations is shown in figure 142. If dimensioned lumber is unavailable, tanks can be elevated by constructing log-crib, masonry, or concrete supports. Expedient supports for a large tank can be constructed from empty fuel drums. (See fig. 71.) For construction details of 36-foot towers, see TM 5-280.

(3) *Operating platforms.* Operating efficiency at poorly drained water points is increased by installing platforms to keep the personnel out of the mud. These platforms may be duckboards or corduroy mats. On sloping ground, the equipment platforms can be extended and joined to form operating platforms. (See fig. 143.)

c. FLOATING SUPPORTS. If conditions are favorable, relatively heavy distillation units can be made more mobile by installing them on rafts. (See fig. 144.)

d. MISCELLANEOUS EXPEDIENTS. At many water points, the terrain demands ingenious expedients. In Italy, a stream lying between high sloping banks and subject to flash floods was used by installing a Bailey bridge over the stream as a foundation for the water purification equipment. Another site was used despite enemy sniper fire by building log revetments around the equip-

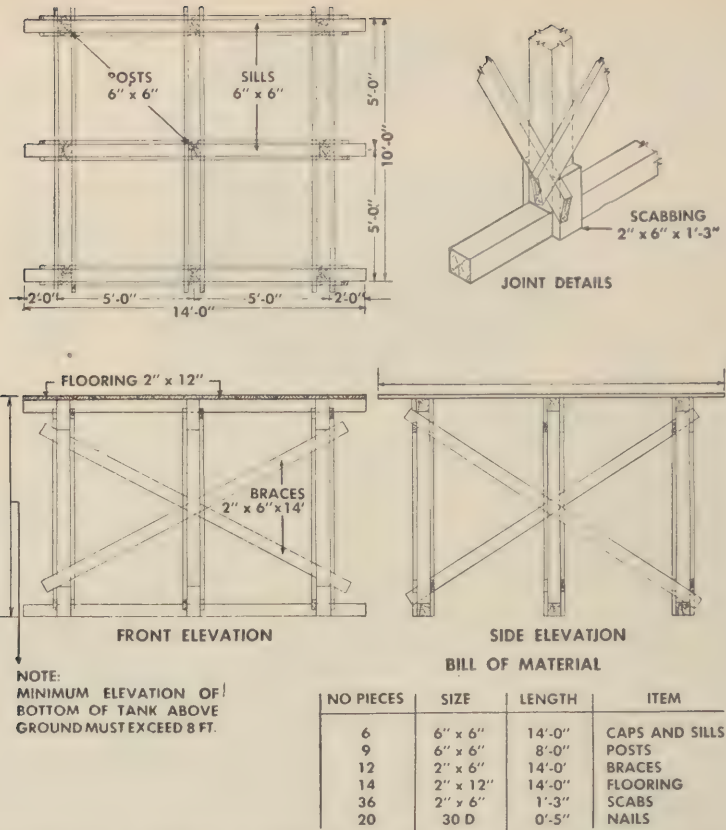


Figure 141. Details of elevated platform for 3,000-gallon tank using dimensioned lumber.

ment. At the same site, the portable equipment was trailer-mounted and moved to the rear each night. (For trailer mounting, see par. 73.)

161. Storage Facilities

Storage facilities should be large enough to meet daily peak demands, thus eliminating long waits at the water point by consumers.

a. CANVAS TANKS. Canvas or fabric tanks deteriorate rapidly and must be replaced from depot stock. Additional canvas tanks are required for turbid sources which require settling.

b. EXPEDIENTS. Excavations lined with tarpaulin (tank covers or truck tops) can be used for additional storage facilities. (See fig. 145.) The spoil from the excavation should be piled around the edges to prevent surface drainage polluting the stored water.

c. DEPOT STOCK. Wood or metal storage tanks are carried in



Figure 142. Three-thousand-gallon tank on elevated platform of dimension lumber installed to supply hospital in corps area.

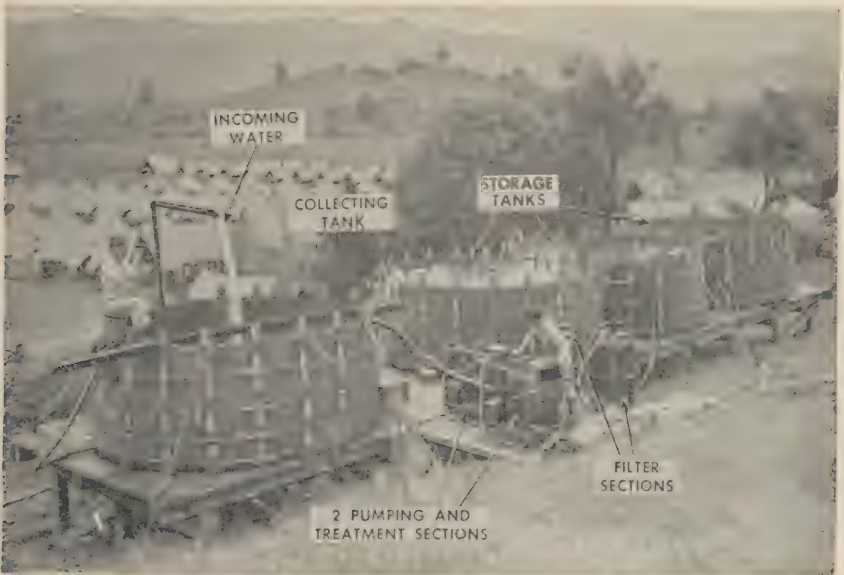


Figure 143. Portable purification units supplying water to a semipermanent camp. Note how use of platforms has improved working conditions at this hillside water point.

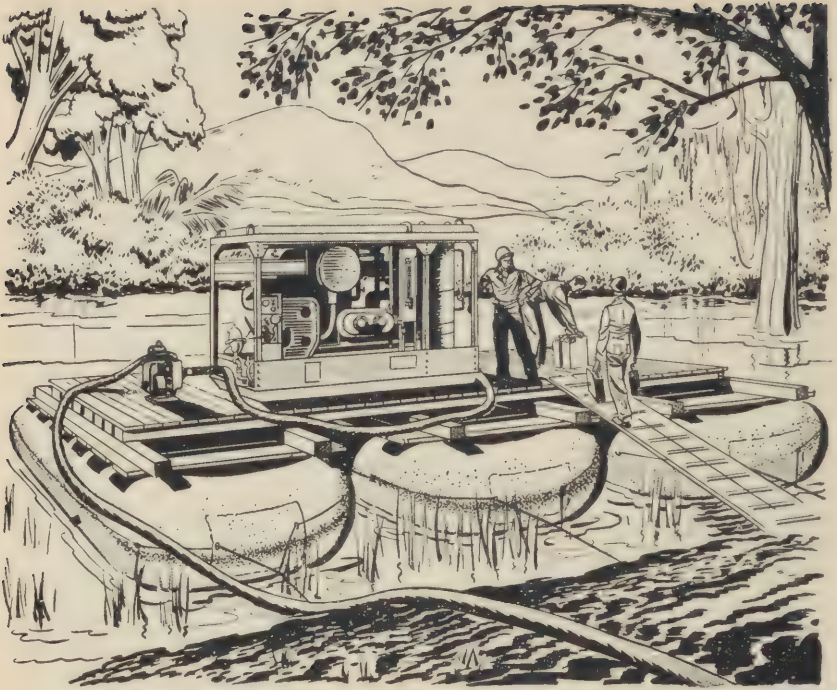


Figure 144. Three-thousand-gpd thermocompression unit installed on three-ponton raft.

engineer depots as class IV supplies. They are designed for field erection and vary in size from 500 to 25,000 gallons. (See TM 5-280.)

162. Communications

a. TURN-OUTS AND TURN-AROUNDS. When water points are located along traveled roads, facilities must be provided for loading consumers' trucks without interfering with normal traffic. A turn-out is satisfactory for small installations. Turn-outs may be a widened section of the main road (fig. 161) or a new one-way road past the water point (fig. 138), depending on the labor available. For large installations, a turn-around is helpful. (See fig. 146.) As both turn-outs and turn-arounds are low-type roads, they must have good drainage to carry off spillage. Improper construction of these facilities soon causes a water point to become useless. (See fig. 139.) (For construction principles, see FM 5-10.)

b. TRAFFIC SIGNS. Traffic signs marking the route to the water point are made and posted by water supply personnel. Signs (fig. 147) should be easy for vehicle drivers to read and posted so



Figure 145. Expedient water storage basin made by lining an excavation with tarpaulin. Spoil from the excavation should be piled around the sides to prevent pollution by surface drainage.

trucks are routed with a minimum of cross-traffic interference. They should be posted at all critical points such as side roads, crossroads, and forks within a 2-mile radius of the water point. Under blackout conditions, a combination of luminous buttons on the signs is helpful.

163. Standpipes and Pipe Lines

Many difficult distribution problems can be solved by using rigid pipe in standpipes or pipe lines. The pipe can be requisitioned from engineer depots or salvaged from damaged civilian installations.

a. STANDPIPES. A water-point standpipe is a rigid pipe which supplies water under pressure from an outlet high enough to service tank trucks. The usual construction is a 2-inch pipe fastened to a vertical timber support. (See fig. 148.) A series of standpipes can be installed on one underground header. The most satisfactory outlet for standpipes is a short length of rubber suction hose with a safety nozzle. The safety nozzle should be suspended so it cannot touch the ground and become contaminated.

b. PIPE LINES. (1) *Use.* Pipe lines are used to carry water

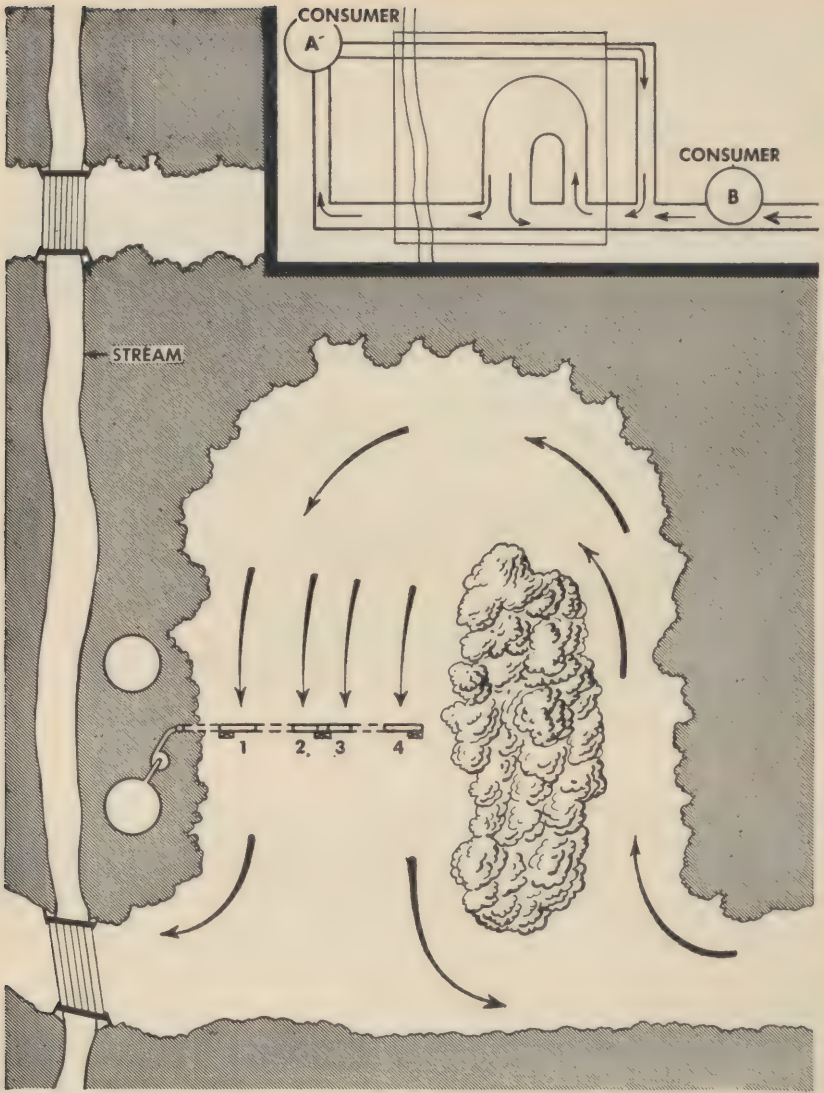


Figure 146. Plan of turn-around at centrally located water point. Note circular traffic plan shown in insert.

over terrain impassable to trucks. A complete pipe line consists of a power-driven pump, rigid pipe and fittings, pipe supports to bridge depressions, and a receiving reservoir. The pumping sets furnished with portable or mobile units do not develop enough pressure for general pipe-line use. Pumps with higher heads for this work are stocked in engineer depots.

(2) *Design.* Procedure in determining design of pipe-line system is as follows:



Figure 147. Signs for directing traffic to water points.



Figure 148. Standpipes installed in parallel at a turnaround.

(a) Select route of proposed pipe line, being careful to avoid abrupt changes in elevation and direction.

(b) Sketch route of pipe line and determine approximate length (l) in feet and difference of elevation (H) in feet, plus or minus, between the average water levels in the distributing and receiving tanks.

(c) List number of valves and fittings and convert to equivalent lengths of straight pipe (le), using the values given for the various sizes of available pipes in table XXX.

(d) Determine total length of straight pipe (L) by adding l and le for the various pipe sizes.

(e) Determine rate of flow through line (gpm) by dividing gallons of water to be pumped by pumping time (minutes). The longer the pump can operate on a fixed amount of water, the smaller size pump and pipe required to do the job.

(f) Consult table XXIX and determine the friction in feet per 1,000 feet of pipe (f) for the various sizes of available pipe. Use the gpm found in (e) above.

(g) Calculate total friction loss (F) by the following formula.

$$F = \frac{f L}{1000}$$

(h) Calculate required pump head (h) in feet by adding difference of elevation (H) to F .

(i) Calculate required pump horsepower ($rh p$) by the formula:

$$rh p = \frac{gpm \times h}{3960}$$

(j) Calculate horsepower (hp) of available pumping set by using rated gpm and rated head in feet of the pumps in the following formula:

$$hp = \frac{gpm \times \text{rated head in feet}}{3960}$$

(k) List h and $rh p$ for each diameter of available pipe and compare with hp and developed head of the various available pumping sets. Select the smallest diameter pipe which requires the smallest pumping set.

(3) *Example of equipment selection.* (a) *Requirement.* To design a pipe line supplying 12,000 gallons in 7 hours to a combat team located 3 miles from the water point, using the following materials:

1. *Pipe.* 2-, 3-, or 4-inch-diameter new wrought-iron pipe.

2. *Pumping sets.* All gasoline-engine-driven.

Centrifugal 2-in, Jaeger 2APSI, 55-gpm at 50 feet.

Centrifugal 2-inch, Gorman Rupp W52-10, 60-gpm at 125 feet.

Centrifugal 4-inch, Gorman Rupp C54-14, 200-gpm at 350 feet.

Centrifugal 1½-inch Economy B-180, 125-gpm at 300 feet.

Centrifugal 4-inch, Aurora AD2, 480-gpm at 300 feet.

(b) After selecting route, length of pipe (L) is found to be 3.4 miles or 17,952 feet. Difference in elevation (H) is + 130 feet.

| (c) Valves and fittings | Equivalent length of pipe | | |
|-----------------------------|---------------------------|--------|--------|
| | 2-inch | 3-inch | 4-inch |
| 2 gate valves | 2.4 | 3.4 | 4.6 |
| 6 standard elbows | 33.0 | 48.6 | 66.0 |
| 2 tees | 22.0 | 34.0 | 44.0 |
| Loss at pipe entrance | 3.0 | 4.5 | 6.0 |
| Total le in feet | 60.4 | 90.5 | 120.6 |

(d) *Total length of straight pipe.*

For 2-inch pipe, $L = 17,952 + 60.4 = 18,012.4$. Use 18,020 feet.

For 3-inch pipe, $L = 17,952 + 90.5 = 18,042.5$. Use 18,050 feet.

For 4-inch pipe, $L = 17,952 + 120.6 = 18,072.6$. Use 18,080 feet.

(e) Rate of flow through line in *gpm*.

$$12,000 = 28.6 \text{ Use } 30 \text{ gpm.}$$

$$7 \times 60$$

(f) Friction loss in feet per 1,000 feet of pipe (f) from table XXIX. Note that values in the table must be multiplied by a factor of .715 for new wrought-iron pipe.

| Pipe diameter | gpm | f (from table) | corrected f |
|---------------|-----|------------------|---------------|
| 2-inch | 30 | 38.4 feet | 27.5 feet |
| 3-inch | 30 | 5.4 feet | 3.9 feet |
| 4-inch | 30 | 1.32 feet | .94 feet |

$$(g) \text{ Total friction loss, } F = \frac{f L}{1000}$$

| Pipe diameter | F |
|---------------|----------|
| 2-inch | 496 feet |
| 3-inch | 70 feet |
| 4-inch | 17 feet |

(h) Required pump head, $h = H + F$

| Pipe diameter | h |
|---------------|----------|
| 2-inch | 626 feet |
| 3-inch | 200 feet |
| 4-inch | 147 feet |

$$(i) \text{ Required pump horsepower, } rhp = \frac{\text{gpm} \times h}{3960}$$

| Pipe diameter | rhp |
|---------------|------|
| 2-inch | 4.77 |
| 3-inch | 1.51 |
| 4-inch | 1.09 |

$$(j) \text{ Hp of available pumps, } hp = \frac{\text{gpm} \times \text{rated head}}{3960}$$

| Pump | hp | Rated head |
|--------------------|-------|------------|
| Jaeger 2APSI | 0.695 | 50 feet |
| Gorman Rupp W52-10 | 1.89 | 125 feet |
| Gorman Rupp C54-14 | 17.70 | 350 feet |
| Economy B-180 | 9.46 | 300 feet |
| Aurora AD2 | 36.40 | 300 feet |

(k) *Comparison of data.*

| Pipe diameter | h | rhp |
|---------------|----------|------|
| 2-inch | 626 feet | 4.77 |
| 3-inch | 200 feet | 1.51 |
| 4-inch | 147 feet | 1.09 |

Two-inch diameter pipe cannot be used because h is too high. The operating characteristics of the available pumping sets make the difference between the h and rhp for the 3- and 4-inch-diameter pipes negligible. Therefore, the 3-inch pipe is selected because it is easier to handle and install.

The pump used must develop a head greater than 200 feet and a horsepower (hp) greater than 1.51. The Economy centrifugal pumping set comes closest to meeting these requirements.

Conclusions.

1. Requisition 20,000 feet of 3-inch-diameter pipe and fittings.
2. Requisition one Economy centrifugal pump, 1½-inch, B-180.

Note. These conclusions are based on the assumption that the use of a second pump at the halfway point of the pipe line is tactically undesirable. The use of remotely located booster pumps is seldom desirable in front-line installations. In rear areas where the booster pump can be used, two Gorman-Rupp W52-10 pumps should be used in series.

164. Dry Points

A dry point is a water point established for distributing treated water. It has neither a raw-water source nor purification equipment, and receives its supply of potable water from a water-treatment point. Dry points solve many difficult water supply problems by permitting the installation of the treatment equipment at the best water source and the erection of the distributing facilities at the most convenient location for consumers. Treated water is then trucked from the treatment point to the dry point.

Several dry points served by a single water point are useful when the bulk of the water goes to a few large users such as bakeries, hospitals, and encampments. A piping diagram for a hospital dry point is shown in figure 149. A close-up view of the elevated tank is shown in figure 142.

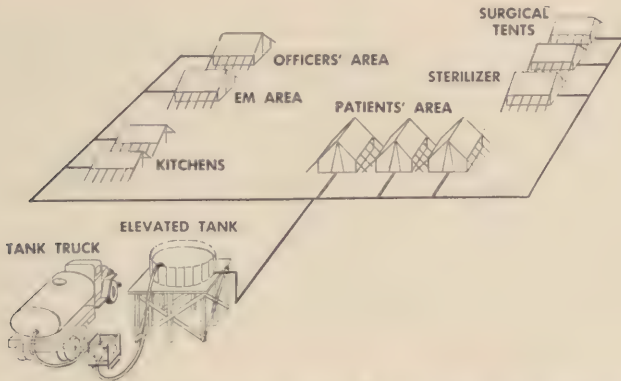


Figure 149. Piping diagram for a hospital dry point in corps area.

165. Camouflage

Water points must use camouflage to increase security. (See FM 5-20.) Where overhead concealment is lacking, the form and shadows of equipment must be broken by camouflage nets or field expedients. Since tire tracks reveal the location of distributing equipment, it should be as far as possible from treating equipment.

Section IV. LAY-OUT OF WATER-TREATING EQUIPMENT

166. General

a. Almost any combination of impurities in water can be removed or destroyed if issue Army water purification equipment is correctly laid out and operated. Equipment is covered in chapters 4 and 5. This section covers the lay-out of equipment to produce potable water under specific field conditions.

b. Water purification equipment is generally issued in sets which include the necessary auxiliary equipment and supplies for field operation. Appendix I lists the equipment in the various sets. These sets are designed to remove or destroy impurities in fresh water by coagulation, sedimentation, filtration, and disinfection, or by any combination of these processes. Two other processes, adsorption and aeration, can be used by proper arrangement of the issued equipment to remove objectionable tastes, colors, and

odors caused by dissolved gases or liquids. Dissolved solids can be removed by distillation.

c. Lay-outs or flow diagrams shown in this section cover the major combinations, but the adaptability of the equipment makes possible many other arrangements to solve specific purification problems.

d. Activated carbon is used to absorb objectionable tastes, colors, or odors from water. (See par. 42.) Any lay-out with a sedimentation tank before the filter assembly is satisfactory when using this treatment.

e. Estimated capacity or output for each lay-out is comparative. It is based on a 20-hour production day and the equipment capacities given in chapters 4 and 5.

f. Storage facilities have not been considered in estimating daily output of the various lay-outs. The effect of inadequate storage facilities can be offset by prompt distribution of the treated water.

167. Portable Purification Unit

The portable purification unit is normally issued as a component part of water supply equipment set No. 1. The complete set consists of a pumping and treatment assembly, a rapid sand-filter assembly, two 3,000-gallon canvas tanks, three auxiliary pumping sets, flexible hose, fittings, chemicals, and control equipment. This set is designed for use by divisional engineers on water sources of widely varying quality. The unit with its auxiliary equipment readily produces potable water from most sources.

a. PUMPING AND TREATMENT ASSEMBLY (fig. 150). If the source requires disinfection only, the pumping and treatment assembly can be used without the filter assembly to increase the residual-chlorine content of the clear water. Water chlorinated this way must stand 30 minutes before use. However, field sources are not generally clear enough to omit filtration. Based on an output of 55 gpm, daily production with this lay-out is approximately 66,000 gallons per 20-hour day.

b. WITHOUT PUMPING AND TREATMENT ASSEMBLY (fig. 151.)

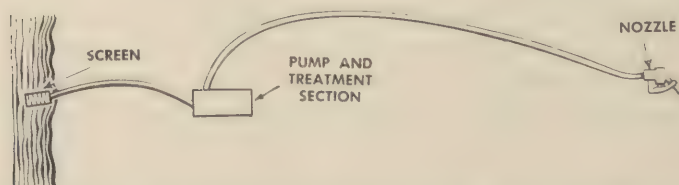


Figure 150. Lay-out for pumping and treatment assembly without filter.

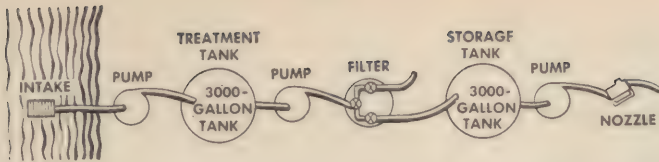


Figure 151. Lay-out without pumping and treatment assembly.

If the pumping and treatment assembly is damaged or destroyed, potable water can still be produced from normal field sources by adding coagulating and disinfecting chemicals manually. However, this is an expedient batch method and does not compare in ease of operation to the continuous mechanical-feeder method (fig. 152) using the pumping and treatment assembly. When one sedimentation tank (3,000-gallon capacity) is used, this layout is capable of producing approximately 2,500 gallons on a 6-hour cycle or 8,300 gallons per 20-hour day. Using two sedimentation tanks, the capacity increases to approximately 10,500 gallons per 20-hour day.

c. PORTABLE UNIT WITHOUT SEDIMENTATION (figs. 152, 153, and 154). For clear sources (turbidity less than 50 ppm) containing no unusual contamination or pollution, the portable unit can pro-



Figure 152. Portable unit installed without sedimentation tanks for processing water from a clear stream.

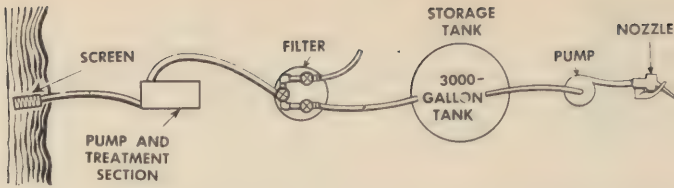


Figure 153. Lay-out of portable unit without sedimentation.

duce potable water by coagulation, filtration, and disinfection without sedimentation. However, floc flowing directly to the filter puts a heavy load on it and necessitates fairly frequent backwashing. Daily output from slightly turbid sources does not exceed 11,000 gallons per 20-hour day. The outstanding disadvantage of this arrangement is the greatly decreased capacity and quality of output with small increases in the turbidity of the source. The effect of disturbances in surface-water sources can be minimized by using improved intakes.

d. SEDIMENTATION AFTER PUMPING AND TREATMENT ASSEMBLY (fig. 155). A sedimentation tank between the pumping and treatment assembly and the filter assembly is recommended

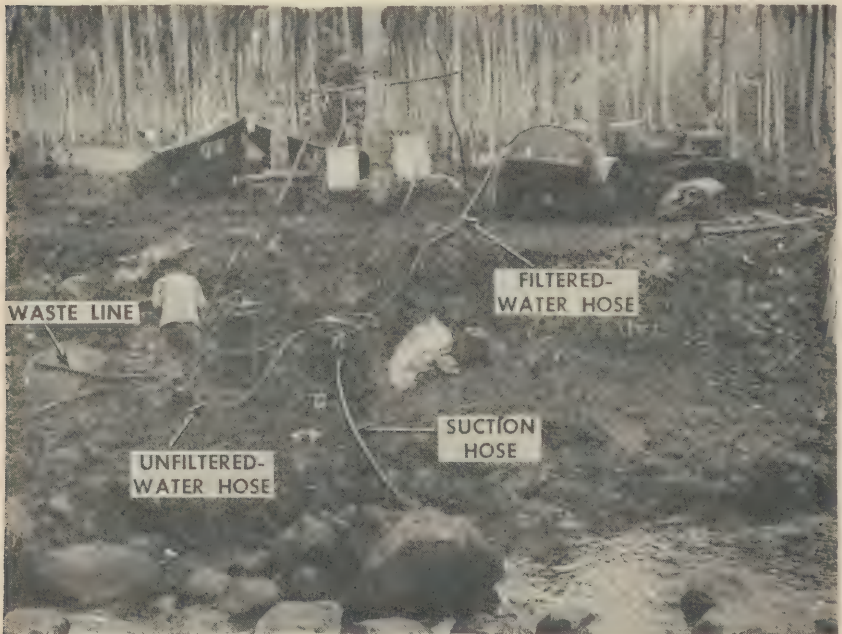


Figure 154. Portable unit installed at a forward water point in the Southwest Pacific. The lay-out does not use sedimentation and the storage tank has not been erected. Note the Lyster bags for storing water for canteens.

for waters that are difficult to coagulate. Longer filter runs result from the decreased load effected by the settling out of suspended particles. For highly turbid sources, the lay-out has the disadvantage of taking the suspended solids through the pumping and treatment assembly, causing some wear to the venturi tube and pump impeller. With one sedimentation tank, the average daily production is approximately 8,300 gallons per 20-hour day. With two sedimentation tanks, the average daily production is approximately 10,500 gallons per 20-hour day.

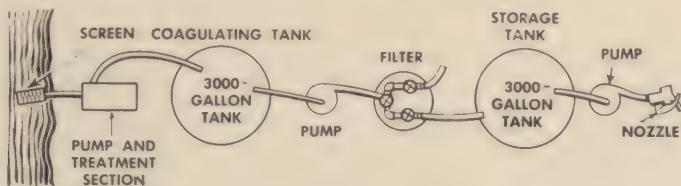


Figure 155. Lay-out for sedimentation after pumping and treatment assembly.

e. SEDIMENTATION BEFORE PUMPING AND TREATMENT ASSEMBLY (fig. 156). A lay-out with sedimentation tank before the pumping and treatment assembly is recommended for highly turbid sources and those contaminated with schistosomes. This permits using the same combination of purification processes as shown in figure 155. With highly turbid sources, wear on the pumping and treatment unit is reduced. When coagulation is combined with sedimentation, the coagulating chemicals can be added by hand or by a wire basket (par. 83a) placed in the influent stream. For normal sources the average daily production with this lay-out is the same as with the lay-out shown in paragraph 167d, but the work involved is greater.

f. CONTINUOUS-FLOW PRETREATMENT. (1) Use. Continuous-flow pretreatment (par. 36d) may be used with an equipment arrangement which provides for a pumping and treatment assembly followed by a settling tank. (See fig. 155.) It is especially advantageous when treating water with a single settling tank. It is less certain than batch pretreatment because of the danger of the water

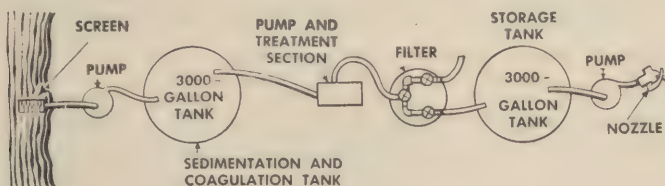


Figure 156. Lay-out for sedimentation before pumping and treatment assembly.

short-circuiting in the settling tank. The tank inlet and outlet should be arranged as shown in figure 157 to obtain maximum settling time. The rate of flow into and out of the tank must be equal at about 10 gpm.

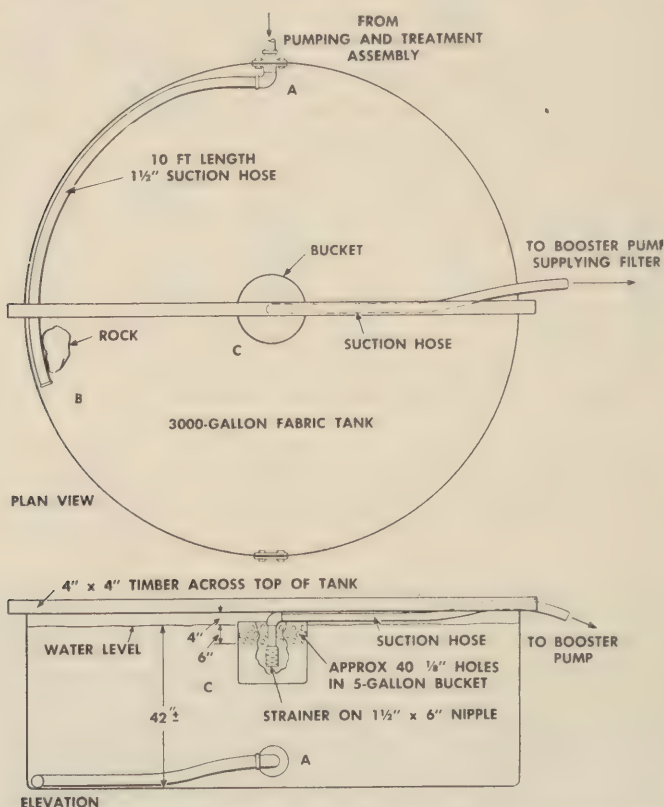


Figure 157. Arrangement of inlet and outlet on 3,000-gallon settling tank for continuous-flow pretreatment.

(2) *Operating instructions.* The simplest operating procedure for continuous-flow pretreatment is as follows:

(a) Install the equipment as shown in figure 155.

(b) Connect the discharge from the pumping and treatment assembly through the side of the tank so the influent stream flows along the bottom of the tank wall tangentially. (See fig. 157.)

(c) Fill the tank about three-quarters full of untreated water and stop the pump.

(d) Manually add the coagulant dosage determined by jar test (par. 58) and agitate gently until floc begins to form.

(e) Suspend the outlet strainer in a perforated bucket placed in the center of the tank and low enough to be covered when the water level is 4 inches from the top of the tank. (See fig. 157.)

(f) Pump water into the tank at the rate of 10 gpm and adjust the coagulant feeders to maintain the water at the optimum pH. Adjust the hypochlorinator to give a residual chlorine content of 1 ppm at the tank outlet.

(g) When the water is 4 inches from top of tank, start the booster pump and regulate it to maintain a constant level in the settling tank.

Note. If both pumps operate at 10 gpm and the settling tank inlet and outlet devices are properly installed, a settling period of about 1 hour can be attained.

g. SEDIMENTATION BEFORE AND AFTER PUMPING AND TREATMENT ASSEMBLY (fig. 158). Double sedimentation with coagulation is advantageous for treating water contaminated by schistosomes and amoebic cysts. Multiple settlings with coagulation greatly reduces the number of amoebic cysts in the water and if this treatment is followed by slow filtration, the cysts are effectively removed. Wherever possible, sources contaminated with either schistosomes or cysts causing amoebic dysentery should be avoided, as treatment of these sources is hazardous.

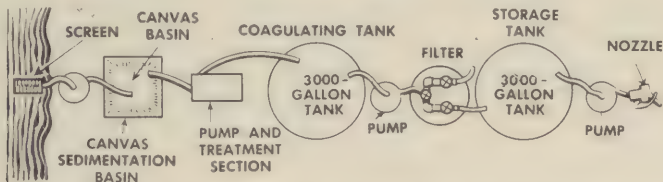


Figure 158. Lay-out for sedimentation before and after pumping and treatment assembly.

h. WITH AERATION (figs. 159 and 160). Some waters with objectionable tastes or odors can be made potable by spraying water into a tank through an intake strainer attached to the discharge hose of a pump. Waters containing dissolved gases usually yield readily to this treatment. (For details on aeration, see paragraph 42b (1).)

i. BOOSTER PUMP BEFORE PUMPING AND TREATMENT ASSEMBLY (figs. 161 and 162). A booster pump can be attached before the

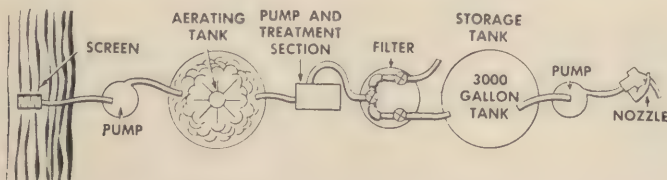


Figure 159. Lay-out for aeration of raw water.

pumping and treatment assembly, demonstrating the adaptability of the portable unit in overcoming problems other than those caused by poor quality of the source. A source more than 20 feet below or more than 150 feet away from the unit can be used by placing the booster pump at the source and pumping the water to the unit. This layout is helpful when overhead concealment is far from the source. (See fig. 161.)

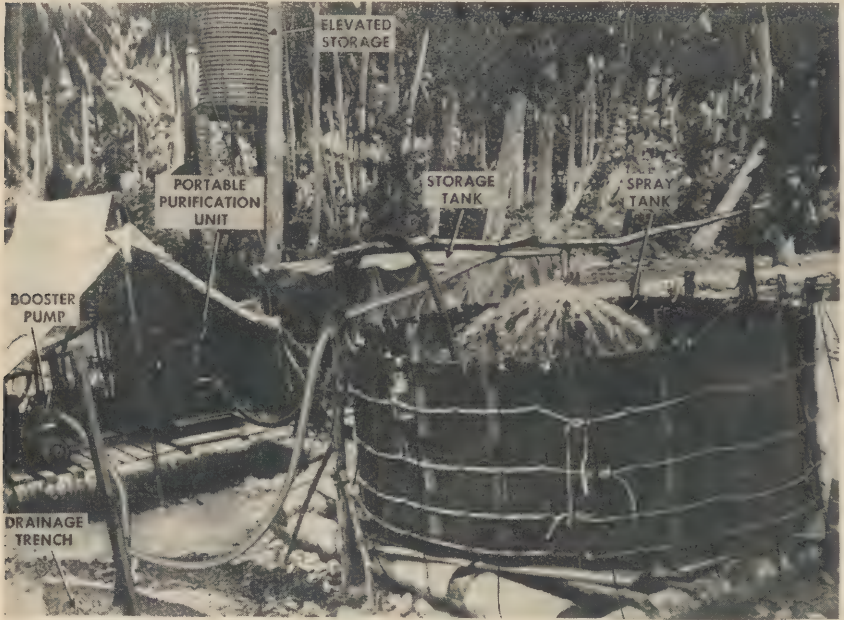


Figure 160. Portable purification unit arranged for aeration of raw water at semipermanent installation in Fiji Islands.

168. Mobile Purification Unit

The mobile purification unit uses the same type of equipment as the portable purification unit. Since the basic design of both units involves a rapid sand filter, lay-outs for these units have the same advantages and disadvantages. Auxiliary equipment (water supply equipment set No. 5) for the mobile unit is listed in ASF Supply Catalog ENG 2.

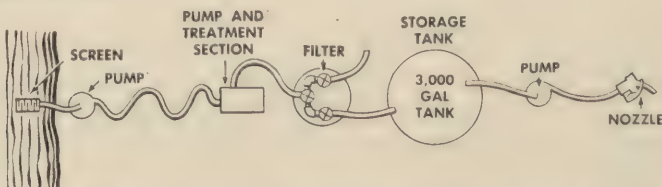


Figure 161. Lay-out for using booster pump before pumping and treatment assembly.

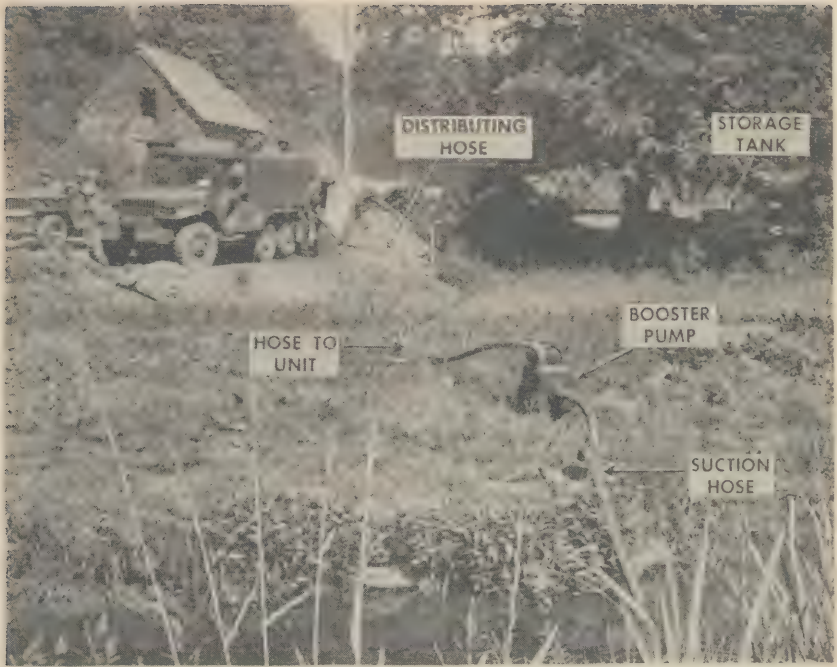


Figure 162. Portable purification unit installed at forward water point in France. Note use of booster pump to allow locating unit under trees. Turn-out is merely wide space in road.

The principal differences between the two units are the higher output and the truck mounting of the mobile unit.

a. MOBILE UNIT WITHOUT SEDIMENTATION (fig. 163). The processes of the mobile and portable units without sedimentation are the same. (See par. 167c.) This lay-out is used on sources of low turbidity with no unusual impurities. Maximum production is approximately 66,000 gallons per 20-hour day.

b. SEDIMENTATION BETWEEN UNIT AND SOURCE (figs. 164 and 165). Lay-out with a sedimentation tank before the mobile unit is normal for muddy sources, and is essential for sources contaminated by schistosomes. Processing with this lay-out is the same as for the portable unit. (See par. 167.) When coagulation is com-

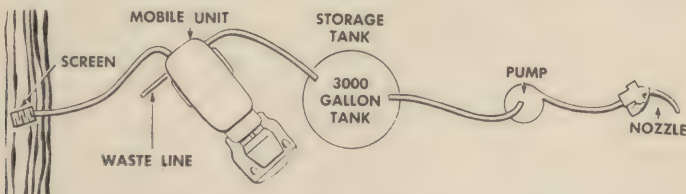


Figure 163. Lay-out for mobile unit without sedimentation.

bined with sedimentation, the coagulants can be added manually or in a wire basket placed in the influent stream. With one sedimentation tank, production of potable water is approximately 27,000 gallons per 20-hour day; with two sedimentation tanks, production is approximately 47,000 gallons; and with three sedimentation tanks, production is approximately 57,000 gallons.

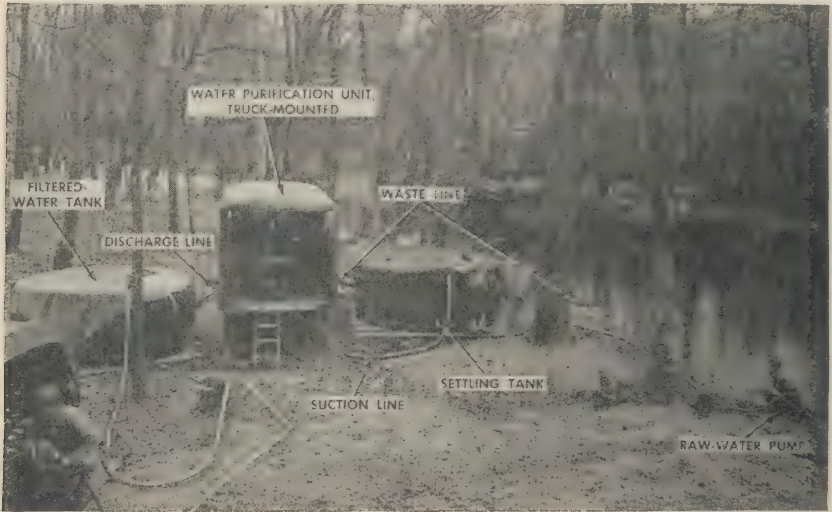


Figure 164. Mobile unit using sedimentation between unit and water source.

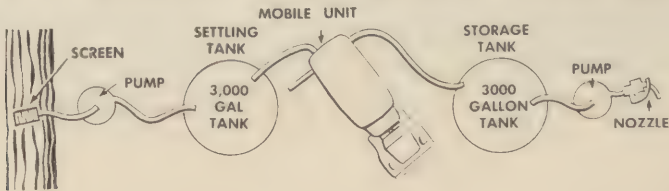


Figure 165. Lay-out for mobile unit with sedimentation between unit and source.

c. SEDIMENTATION BETWEEN PUMPING AND TREATMENT ASSEMBLY AND FILTER. (1) Where desirable to add coagulating or disinfecting chemicals to the sedimentation tank automatically the sedimentation tank can be placed in the line of flow between the pumping and treatment assembly and the filter. The processes used are the same as for the portable-unit lay-out. (See fig. 155.) However, this lay-out decreases mobile-unit production because the pump mounted on the mobile-unit truck must be used first for filling the sedimentation tank and later for forcing the settled water through the filter. One method for installing and operating this lay-out is as follows:

- (a) Set up a 3,000-gallon tank.
 - (b) Connect intake hose to suction of 100-gpm. pump.
 - (c) Place discharge hose from unit in sedimentation tank and open quick-acting valve on this line.
 - (d) Cap waste-line connection on unit.
 - (e) Turn five-way valve to wash position.
 - (f) Start pump and chemical feeds and fill sedimentation tank.
 - (g) Settle floc for about 30 minutes.
 - (h) Place suction hose from pump in sedimentation tank.
 - (i) Remove discharge hose of unit from sedimentation tank and close quick-acting valve.
 - (j) Remove cap from waste-line connection.
 - (k) Filter as in normal operation.
- (2) Production by this arrangement is approximately 24,000 gallons per 20-hour day. Compared to the lay-out with the sedimentation tank between the unit and the source (*b* above), this lay-out wastes time, equipment, and water.

169. Diatomite Purification Equipment

The 15- and 50-gpm diatomite water purification sets are built around the recently developed diatomite filters. (See pars. 74 and 80.) Both sets are especially designed to remove cercariae of schistosomes and amoebic cysts. Pretreatment is advantageous for efficient operation of the diatomite filter.

a. 15-GPM DIATOMITE WATER PURIFICATION EQUIPMENT, NINE MAN PACKS. When all the equipment of the 15-gpm diatomite set is available, it should be laid out as shown in figure 166. This lay-out uses coagulation, sedimentation, disinfection, and filtration to obtain the maximum capacity and highest quality of output regardless of the turbidity of the source. If the raw water has an objectionable taste, color, or odor, the process of adsorption can be used by adding activated carbon to the pretreatment tanks. Maximum production of potable water with this lay-out is approximately 15,000 gallons per 20-hour day.

b. 15-GPM DIATOMITE WATER PURIFICATION EQUIPMENT, SIX

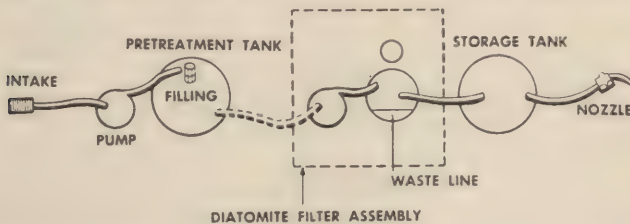


Figure 166. Lay-out of 15-gpm diatomite water purification equipment, complete, nine man packs.

MAN PACKS. When only six men or two mules are available to transport the 15-gpm diatomite set, packs 1, 2, 3, 5, 6, and 9 should be carried and the equipment should be set up as shown in figure 167. This lay-out produces high-quality water regardless of the turbidity of the source. Maximum production with this lay-out is limited to approximately 6,500 gallons per 20-hour day, because processing is done in batches. The pump must be used first to fill the pretreatment tank and then to pump the settled water through the filter.

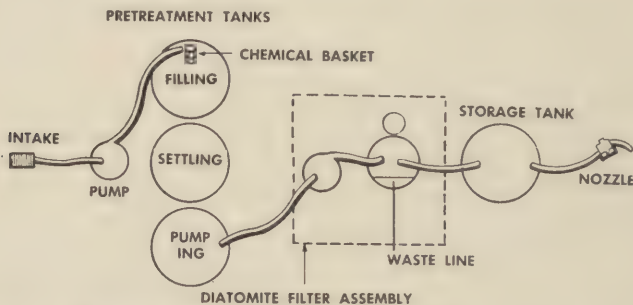


Figure 167. Lay-out of 15-gpm diatomite water purification equipment carried in six-man packs.

c. **15-GPM DIATOMITE WATER PURIFICATION EQUIPMENT, THREE MAN PACKS.** When only three men or one mule are available to transport the 15-gpm diatomite set, packs 1, 2, and 3 should be carried and the equipment arranged at the water point as shown in figure 168. This lay-out is used only in emergencies, as no provision is made for pretreatment. Potable water can be produced only in small quantities, by this lay-out, unless the source is exceptionally clear. Water is disinfected by adding the calcium hypochlorite to the slurry-feed tank on the filter or directly to the consumers' containers. Turbidity affects the filter capacity so greatly that daily production with this lay-out is unpredictable.

d. **50-GPM DIATOMITE WATER PURIFICATION EQUIPMENT WITH PRETREATMENT.** Figure 169 shows the recommended lay-out for 50-

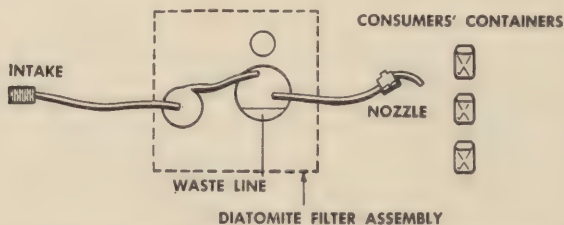


Figure 168. Lay-out of 15-gpm diatomite water purification equipment carried in three-man packs.

gpm diatomite water purification equipment. This lay-out permits the use of coagulation, sedimentation, disinfection, and filtration, and can produce potable water from turbid sources contaminated with cercariae of schistosomes and amoebic cysts. It is essentially the same as the lay-out for the 15-gpm diatomite equipment shown in figure 166. Production of potable water with this lay-out is approximately 52,000 gallons per 20-hour day.

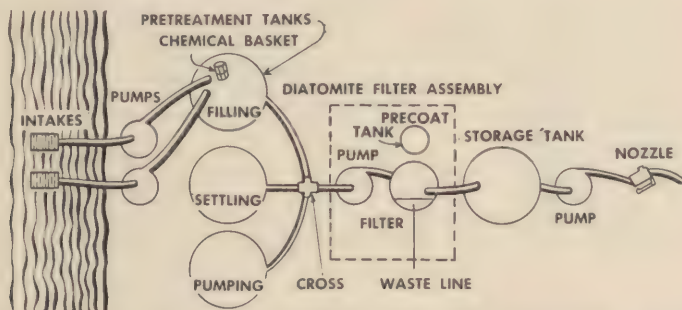


Figure 169. Lay-out of 50-gpm diatomite water purification equipment with pretreatment.

e. 50-GPM DIATOMITE WATER PURIFICATION EQUIPMENT WITHOUT PRETREATMENT. Figure 170 shows a lay-out for the 50-gpm diatomite equipment without pretreatment. It is satisfactory when used with exceptionally clear sources such as municipal systems and deep wells. The water is disinfected by adding the calcium hypochlorite to the slurry-feed tank or to the filtered-water storage tank. With this lay-out, turbidity affects the filter capacity so greatly that no predictions can be made as to daily production of potable water.

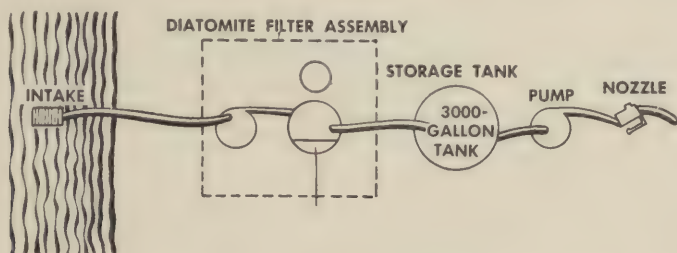


Figure 170. Lay-out for 50-gpm diatomite water purification equipment for emergency use.

170. Distillation Equipment

a. WATER distillation equipment is available in depots as class IV supplies for use in areas without fresh-water sources. Lay-outs of equipment vary with the kind and amount of auxiliary equip-

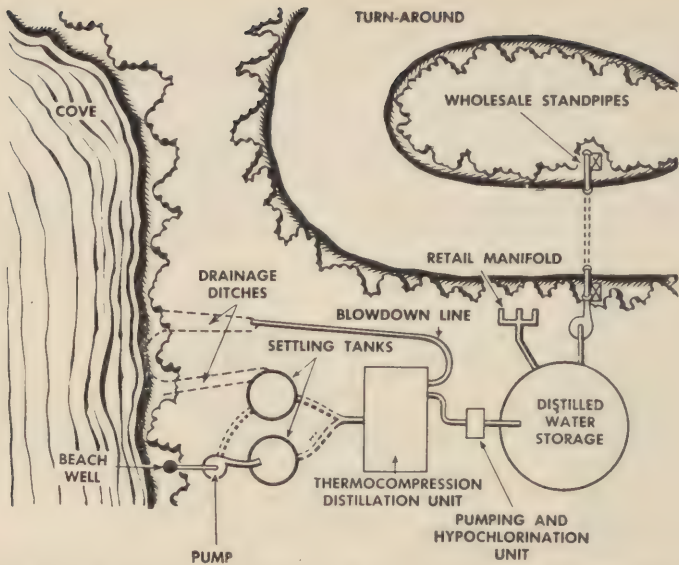


Figure 171. Lay-out for 3,000-gpd thermocompression distillation unit.

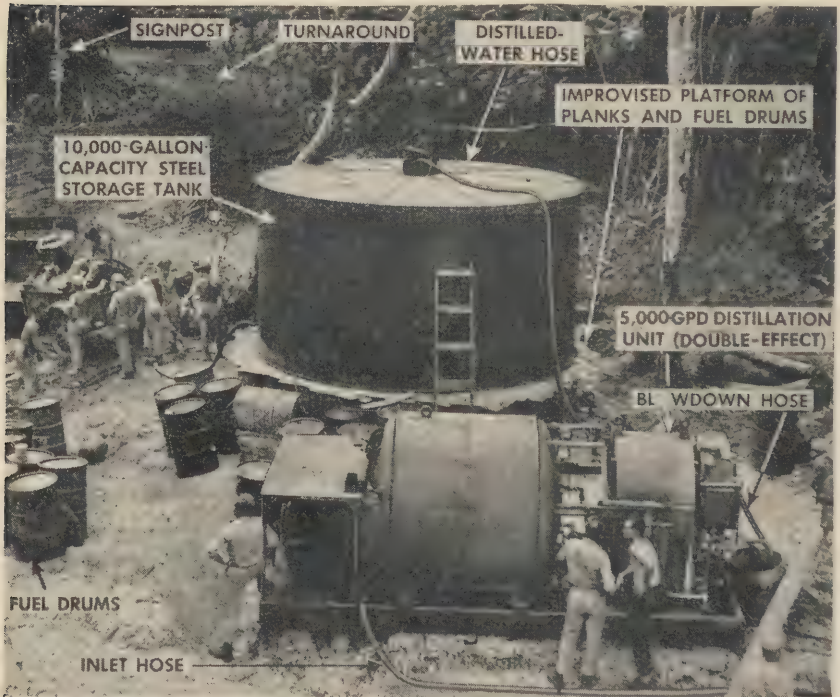


Figure 172. View of a 5,000-gpd double-effect distillation unit located on an open beach. Note tank foundation made from empty fuel-oil drums.

ment in the depots, such as water storage tanks, pumping sets, pipes, and fittings. A satisfactory lay-out must provide for—

- (1) Sea-water intake. (See par. 153.)
- (2) Settling tank for salt water.
- (3) Level, concealed site for distillation unit.
- (4) Storage tank for distilled water. (See par. 161.)
- (5) Distribution facilities. (See par. 163.)

b. Figure 171 shows a suggested lay-out for a 3,000-gpd thermo-compression unit in a sheltered cove. In this lay-out, the distilled water is chlorinated continuously by a 50-gpm pumping and hypochlorinator assembly. (See par. 98.) This assembly is similar to the pumping and treatment assembly of the portable purification unit, which can also be used in this lay-out. If neither assembly is available, the hypochlorite must be added to the water in the storage tank and mixed by recirculating the water with pumps. This batch method should be avoided on large tanks whenever continuous hypochlorinating equipment is available.

c. Figure 172 shows an actual installation of a 5,000-gpd double-effect distillation unit on an open beach. The metal storage tank is typical of the storage facilities available in depots for use with distillation units. Figure 173 shows a semipermanent installation of distillation units.



Figure 173. Distillation units installed in a semipermanent location.

Section V. WATER SUPPLY RECORDS

171. General

a. OBJECTIVES. Water supply records are kept in order to---

- (1) Coordinate the operation of widely separated water points.
- (2) Safeguard water quality.
- (3) Improve efficiency of water treatment and distribution.
- (4) Decrease equipment maintenance.
- (5) Prevent unequal distribution of treated water.
- (6) Obtain supply data for higher headquarters.

b. TYPES OF RECORDS. There are three types of water supply records; daily water-point reports, inspection reports, and headquarters summaries.

c. CHARACTERISTICS. Water supply records must be simple, because water-point personnel are too busy to keep elaborate reports. Reports must contain the minimum of information which will satisfy their objectives.

172. Daily Water-Point Reports

The daily water-point report is the basis for all subsequent water supply records, and any inaccuracy in it affects the record of higher headquarters. The report is usually submitted on two forms similar to those discussed below.

a. DAILY PRODUCTION REPORT. (1) The daily production report form (fig. 174) should be designed so information can be recorded as it is obtained and so it reminds operators of their duties. The form may be modified for specific use.

(2) Daily production figures are usually obtained from distribution reports. Waste can be determined by subtracting distribution from daily production (hours of unit operation by average rate of production).

(3) The information required on tests is valuable in reminding operators of the quality control tests. Reports of routine control tests are unreliable unless verified by frequent inspections.

(4) Equipment operating records are valuable as maintenance aids, since they indicate the dates when pumps and engines were last overhauled. A record of the supplies used insures that the point is promptly restocked and prevents wasteful practices by the operators.

b. DAILY DISTRIBUTION REPORT. The daily distribution report shows the quantity of water drawn by various units and the time it was drawn. These data are usually taken as the basis for daily production figures. The form shown in figure 175 gives a ready

method of recording and reporting this information. It can be modified for specific use.

173. Inspection Reports

a. INSPECTIONS BY WATER SUPPLY OFFICER. Daily inspections of each water point must be made by the responsible officer or his representative. The form shown in figure 176 covers the requirements for a satisfactory field inspection. Inspection times and order of visiting various water points should be changed daily.

b. ROUTINE SAMPLING. The water supply officer or his representative should collect samples of treated water from each water point about three times weekly and send them to the medical laboratory for analysis of bacteria content. Results of these tests are returned to and filed in the headquarters of the unit supplying the water. The record of these tests is valuable in determining the origin of any cases of intestinal diseases.

c. INSPECTIONS BY SANITARY OFFICER. To safeguard the health of consuming troops, water points are inspected at irregular intervals by unit sanitary or medical officers. Chlorine content of water being distributed, sanitation of the water point, and bacteria content of the treated water are carefully checked by these inspections. Bacteriological examinations of the water samples collected are made in the medical laboratory. The sanitary officer can stop production at any water point distributing unsafe water.

174. Headquarters' Summaries

a. DAILY PRODUCTION. A form used to summarize daily production reports is shown in figure 177. Copies of this summary are forwarded to higher headquarters, to the maintenance section, and to the supply section.

b. DAILY DISTRIBUTION. A form of summarizing daily distribution reports is shown in figure 178. This summary should be studied to detect any unusual consumption of water by various units. A copy of this summary is usually requested by high headquarters.

c. MONTHLY OR QUARTERLY REPORTS. Monthly or quarterly activity reports compiled from daily summaries are required by higher headquarters.

| | |
|---|--|
| <hr style="border: 0; border-top: 1px solid black; margin: 0;"/> (organization) | |
| <hr style="border: 0; border-top: 1px solid black; margin: 0;"/> (Water-point Inspection) | |
| <hr style="border: 0; border-top: 1px solid black; margin: 0;"/> (Water point) | <hr style="border: 0; border-top: 1px solid black; margin: 0;"/> (Inspection rating) |
| (Name or map coordinates) | |
| <hr style="border: 0; border-top: 1px solid black; margin: 0;"/> (Date) | <hr style="border: 0; border-top: 1px solid black; margin: 0;"/> (Inspector) |

Residual chlorine: Filter outlet... --ppm. Distributing nozzle... . ppm.

Condition of:

1. Water point (list defects and improvements of lay-out).
2. Equipment (tanks, hose, nozzles, etc.).
3. Engines (list numbers of those needing repairs).
4. Personnel (note sanitation, personal equipment).
5. Remarks.

Signed _____

Figure 176. Report form for water-point inspections.

APPENDIX I

TABLES

Table XVI. International atomic weights

| Sym- bol | Atomic number | Atomic weight | Sym bol | Atomic number | Atomic weight |
|------------------|------------------|------------------|------------------|------------------|------------------|
| Aluminum.....Al | 13 | 26.97 | Molybdenum...Mo | 42 | 95.95 |
| Antimony.....Sb | 51 | 121.76 | Neodymium....Nd | 60 | 144.27 |
| Argon.....A | 18 | 39.944 | Neon.....Ne | 10 | 20.183 |
| Arsenic.....As | 33 | 74.91 | Nickel.....Ni | 28 | 58.69 |
| Barium.....Ba | 56 | 137.36 | Nitrogen.....N | 7 | 14.008 |
| Beryllium.....Be | 4 | 9.02 | Osmium.....Os | 76 | 190.2 |
| Bismuth.....Bi | 83 | 209.00 | Oxygen.....O | 8 | 16.0000 |
| Boron.....B | 5 | 10.82 | Palladium.....Pd | 46 | 106.7 |
| Bromine.....Br | 35 | 79.916 | Phosphorus....P | 15 | 30.98 |
| Cadmium.....Cd | 48 | 112.41 | Platinum.....Pt | 78 | 195.23 |
| Calcium.....Ca | 20 | 40.08 | Potassium.....K | 19 | 39.096 |
| Carbon.....C | 6 | 12.010 | Praseodymium..Pr | 59 | 140.92 |
| Cerium.....Ce | 58 | 140.13 | Protactinium..Pa | 91 | 231 |
| Cesium.....Cs | 55 | 132.91 | Radium.....Ra | 88 | 226.05 |
| Chlorine.....Cl | 17 | 35.457 | Radon.....Rn | 86 | 222 |
| Chromium.....Cr | 24 | 52.01 | Rhenium.....Re | 75 | 186.31 |
| Cobalt.....Co | 27 | 58.94 | Rhodium.....Rh | 45 | 102.91 |
| Columbium....Cb | 41 | 92.91 | Rubidium.....Rb | 37 | 85.48 |
| Copper.....Cu | 29 | 63.57 | Ruthenium....Ru | 44 | 101.7 |
| Dysprosium....Dy | 66 | 162.46 | Samarium.....Sm | 62 | 150.43 |
| Erbium.....Er | 68 | 167.2 | Scandium.....Sc | 21 | 45.10 |
| Europium.....Eu | 63 | 152.0 | Selenium.....Se | 34 | 78.96 |
| Fluorine.....F | 9 | 19.00 | Silicon.....Si | 14 | 28.06 |
| Gadolinium....Gd | 64 | 156.9 | Silver.....Ag | 47 | 107.880 |
| Gallium.....Ga | 31 | 69.72 | Sodium.....Na | 11 | 22.997 |
| Germanium....Ge | 32 | 72.60 | Strontium.....Sr | 38 | 87.63 |
| Gold.....Au | 79 | 197.2 | Sulphur.....S | 16 | 32.06 |
| Hafnium.....Hf | 72 | 178.6 | Tantalum.....Ta | 73 | 180.88 |
| Helium.....He | 2 | 4.003 | Tellurium.....Te | 52 | 127.61 |
| Holmium.....Ho | 67 | 164.94 | Terbium.....Tb | 65 | 159.2 |
| Hydrogen.....H | 1 | 1.0080 | Thallium.....Tl | 81 | 204.39 |
| Indium.....In | 49 | 114.76 | Thorium.....Th | 90 | 232.12 |
| Iodine.....I | 53 | 126.92 | Thulium.....Tm | 69 | 169.4 |
| Iridium.....Ir | 77 | 193.1 | Tin.....Sn | 50 | 118.70 |
| Iron.....Fe | 26 | 55.85 | Titanium.....Ti | 22 | 47.90 |
| Krypton.....Kr | 36 | 83.7 | Tungsten.....W | 74 | 183.92 |
| Lanthanum....La | 57 | 138.92 | Uranium.....U | 92 | 238.07 |
| Lead.....Pb | 82 | 207.21 | Vanadium.....V | 23 | 50.95 |
| Lithium.....Li | 3 | 6.940 | Xenon.....Xe | 54 | 131.3 |
| Lutecium.....Lu | 71 | 174.99 | Ytterbium....Yb | 70 | 173.04 |
| Magnesium....Mg | 12 | 24.32 | Yttrium.....Y | 39 | 88.92 |
| Manganese....Mn | 25 | 54.93 | Zinc.....Zn | 30 | 65.38 |
| Mercury.....Hg | 80 | 200.61 | Zirconium....Zr | 40 | 91.22 |

Table XVII. Molecular and equivalent weights

| Compound | Formula | Molecular weight | Equivalent weight |
|--|--|------------------|-------------------|
| Acetic acid | CH_3COOH | 60.03 | 60.03 |
| Alum, ammonium | $\text{Al}_2(\text{SO}_4)_3 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 24\text{H}_2\text{O}$ | 906.64 | 151.11 |
| Alum, crystals | $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ | 666.43 | 111.07 |
| Alum, potassium | $\text{Al}_2(\text{SO}_4)_3 \cdot \text{K}_2\text{SO}_4 \cdot 24\text{H}_2\text{O}$ | 948.76 | 159.79 |
| Aluminum | A | 26.97 | 8.99 |
| Aluminum hydroxide | $\text{Al}(\text{OH})_3$ | 77.99 | 26.00 |
| Aluminum oxide | Al_2O_3 | 101.94 | 16.99 |
| Aluminum sulfate | $\text{Al}_2(\text{SO}_4)_3$ | 342.14 | 57.02 |
| Ammonia | NH_3 | 17.03 | 17.03 |
| Ammonium chloride (sal ammoniac) | NH_4Cl | 53.50 | 53.50 |
| Ammonium hydroxide | NH_4OH | 35.05 | 35.05 |
| Ammonium nitrate | NH_4NO_3 | 80.05 | 80.05 |
| Ammonium oxalate | $(\text{NH}_4)_2\text{C}_2\text{O}_4$ | 124.08 | 62.04 |
| Ammonium oxalate, crystals | $(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$ | 142.09 | 71.05 |
| Ammonium sulphate | $(\text{NH}_4)_2\text{SO}_4$ | 132.14 | 66.07 |
| Barium carbonate | BaCO_3 | 197.36 | 98.68 |
| Barium chloride | BaCl_2 | 208.27 | 104.14 |
| Barium chloride, crystals | $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ | 244.31 | 122.15 |
| Barium sulfate (barium white) | BaSO_4 | 233.42 | 116.71 |
| Boric acid | H_3BO_3 | 62.02 | |
| Bromine | Br | 79.92 | 79.92 |
| Calcium bicarbonate | $\text{Ca}(\text{HCO}_3)_2$ | 162.10 | 81.05 |
| Calcium carbonate (limestone) | CaCO_3 | 100.08 | 50.04 |
| Calcium chloride | CaCl_2 | 110.99 | 55.50 |
| Calcium hydroxide (slaked lime) | $\text{Ca}(\text{OH})_2$ | 74.10 | 37.05 |
| Calcium oxalate | CaC_2O_4 | 128.08 | 64.04 |
| Calcium oxide (quicklime) | CaO | 56.08 | 28.04 |
| Calcium sulfate (gypsum) | $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ | 172.17 | 86.09 |
| Calcium sulfate (Plaster of Paris) | CaSO_4 | 136.14 | 68.07 |
| Carbon dioxide | CO_2 | 44.00 | |
| Chlorine | Cl_2 | 70.914 | 35.457 |
| Copper sulfate | CuSO_4 | 159.66 | 79.83 |
| Copper sulfate (blue vitriol) | $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ | 249.71 | 124.86 |
| Ferric chloride | FeCl_3 | 162.21 | 54.07 |
| Ferric chloride, crystals | $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ | 270.30 | 90.10 |
| Ferric hydroxide | $\text{Fe}(\text{OH})_3$ | 106.86 | 35.62 |
| Ferric oxide | Fe_2O_3 | 159.68 | 26.61 |
| Ferric sulfate | $\text{Fe}_2(\text{SO}_4)_3$ | 399.86 | 66.64 |
| Ferric sulfate, crystals | $\text{Fe}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$ | 562.00 | 93.67 |
| Ferric sulfocyanate | $\text{Fe}(\text{CNS})_3$ | 230.04 | 76.68 |
| Ferrous ammonium sulfate | $\text{FeSO}_4(\text{NH}_4)_2 \cdot 6\text{H}_2\text{O}$ | 392.13 | 196.07 |
| Ferrous carbonate | FeCO_3 | 115.84 | 57.92 |
| Ferrous hydroxide | $\text{Fe}(\text{OH})_2$ | 89.86 | 44.93 |
| Ferrous sulfate | FeSO_4 | 151.90 | 75.95 |
| Ferrous sulfate, crystals (copperas) | $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ | 278.01 | 139.00 |
| Hydrochloric acid (muriatic acid) | HCl | 36.47 | 36.47 |
| Hydrogen | H_2 | 2.016 | 1.008 |
| Hydrogen sulfide | H_2S | 34.08 | 17.04 |
| Iodine | I | 126.92 | 126.92 |
| Magnesium ammonium phosphate | MgNH_4PO_4 | 137.38 | |
| Magnesium bicarbonate | $\text{Mg}(\text{HCO}_3)_2$ | 146.34 | 73.17 |
| Magnesium carbonate (magnesite) | MgCO_3 | 84.32 | 42.16 |
| Magnesium chloride | MgCl_2 | 95.23 | 47.62 |
| Magnesium hydroxide (milk of magnesia) | $\text{Mg}(\text{OH})_2$ | 58.34 | 29.17 |
| Magnesium nitrate | $\text{Mg}(\text{NO}_3)_2$ | 148.19 | 74.10 |
| Magnesium oxide | MgO | 40.32 | 20.16 |

Table XVII. Molecular and equivalent weights (contd)

| Compound | Formula | Molecular weight | Equivalent weight |
|---|---|------------------|-------------------|
| Magnesium pyrophosphate..... | $\text{Mg}_2\text{P}_2\text{O}_7$ | 222.68 | |
| Magnesium sulfate..... | MgSO_4 | 120.36 | 60.18 |
| Magnesium sulfate, crystals (Epsom salts)..... | $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ | 246.50 | 123.24 |
| Manganic oxide..... | Mn_2O_3 | 157.86 | 26.31 |
| Manganous oxide..... | MnO | 70.93 | 35.47 |
| Manganous sulfate..... | MnSO_4 | 150.99 | 75.50 |
| Manganous sulfate, crystals..... | $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$ | 223.05 | 111.53 |
| Methane..... | CH_4 | 16.03 | |
| Molybdic acid..... | H_2MoO_4 | 162.02 | |
| Nitric acid..... | HNO_3 | 63.02 | 63.02 |
| Oxalic acid..... | $\text{H}_2\text{C}_2\text{O}_4$ | 90.02 | 45.01 |
| Oxalic acid, crystals..... | $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ | 126.05 | 63.02 |
| Oxygen..... | O_2 | 32.00 | 8.00 |
| Phosphoric acid..... | H_3PO_4 | 98.04 | 32.68 |
| Phosphoric pentoxide..... | P_2O_5 | 142.05 | |
| Platinic chloride..... | PtCl_4 | 337.06 | 84.76 |
| Potassium biniodate..... | $\text{KIO}_3 \cdot \text{HIO}_3$ | 389.95 | 32.49 |
| Potassium bromate..... | KBrO_3 | 167.02 | 167.02 |
| Potassium carbonate..... | K_2CO_3 | 138.20 | 69.10 |
| Potassium chloride..... | KCl | 74.56 | 74.56 |
| Potassium chloroplatinate..... | K_2PtCl_6 | 486.17 | |
| Potassium chromate..... | K_2CrO_4 | 194.20 | |
| Potassium cyanide..... | KCN | 65.11 | 65.11 |
| Potassium dichromate..... | $\text{K}_2\text{Cr}_2\text{O}_7$ | 294.20 | 49.04* |
| Potassium ferricyanide..... | $\text{K}_3\text{Fe}(\text{CN})_6$ | 329.19 | |
| Potassium hydroxide (caustic potash)..... | KOH | 56.11 | 56.11 |
| Potassium iodide..... | KI | 166.03 | 166.03 |
| Potassium permanganate..... | KMnO_4 | 158.03 | 31.61* |
| Potassium nitrate (saltpeter)..... | KNO_3 | 101.11 | 101.11 |
| Potassium oxalate, crystals..... | $\text{K}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$ | 184.22 | 92.11 |
| Potassium oxide..... | K_2O | 94.20 | 47.10 |
| Potassium sulfate..... | K_2SO_4 | 174.26 | 87.13 |
| Potassium thiocyanate..... | KCNS | 97.17 | 97.17 |
| Silicon dioxide (silica)..... | SiO_2 | 60.06 | |
| Silver chloride..... | AgCl | 143.34 | 143.34 |
| Silver chromate..... | Ag_2CrO_4 | 331.76 | |
| Silver nitrate..... | AgNO_3 | 169.89 | 169.89 |
| Silver nitrite..... | AgNO_2 | 153.89 | 76.94 |
| Silver sulfate..... | Ag_2SO_4 | 311.82 | 155.91 |
| Sodium bicarbonate (baking soda)..... | NaHCO_3 | 84.00 | 84.00 |
| Sodium carbonate, anhydrous (soda ash)..... | Na_2CO_3 | 105.99 | 53.00 |
| Sodium carbonate (sal soda)..... | $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ | 287.15 | 143.58 |
| Sodium chloride (common salt)..... | NaCl | 58.45 | 58.45 |
| Sodium hydroxide (caustic soda)..... | NaOH | 40.00 | 40.00 |
| Sodium hypochlorite..... | NaOCl | 74.45 | |
| Sodium nitrate (Chile saltpeter)..... | NaNO_3 | 85.01 | 85.01 |
| Sodium oxalate..... | $\text{Na}_2\text{C}_2\text{O}_4$ | 134.00 | 67.00 |
| Sodium phosphate, mono-..... | NaH_2PO_4 | 120.04 | 40.01 |
| Sodium phosphate, di-..... | Na_2HPO_4 | 142.02 | 47.34 |
| Sodium phosphate, tri-..... | Na_3PO_4 | 164.01 | 54.67 |
| Sodium sulfate..... | Na_2SO_4 | 142.05 | 71.03 |
| Sodium sulfate (Glauber's salt)..... | $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ | 322.21 | 161.11 |
| Sodium thiosulfate (hypo)..... | $\text{Na}_2\text{S}_2\text{O}_3$ | 158.11 | 158.11 |
| Sodium thiosulfate, crystals..... | $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ | 248.19 | 248.19 |
| Sulfuric acid (oil of vitriol)..... | H_2SO_4 | 98.08 | 49.04 |
| Sulfurous acid..... | H_2SO_3 | 82.08 | 41.04 |
| Water..... | H_2O | 18.02 | 9.01 |

*Oxidation and reduction in acid medium.

Table XVIII. Chemical reactions in water purification

1. Alum and lime:

$$\text{Al}_2(\text{SO}_4)_3 + 3\text{Ca}(\text{OH})_2 = 2\text{Al}(\text{OH})_3 + 3\text{CaSO}_4$$
2. Alum and soda ash:

$$\text{Al}_2(\text{SO}_4)_3 + 3\text{Na}_2\text{CO}_3 + 3\text{H}_2\text{O} = 2\text{Al}(\text{OH})_3 + 3\text{Na}_2\text{SO}_4 + 3\text{CO}_2$$
3. Alum and alkalinity:

$$\text{Al}_2(\text{SO}_4)_3 + 3\text{Ca}(\text{HCO}_3)_2 = 2\text{Al}(\text{OH})_3 + 3\text{CaSO}_4 + 6\text{CO}_2$$
4. Ferrous sulfate and lime:
 (a) $\text{FeSO}_4 + \text{Ca}(\text{OH})_2 = \text{Fe}(\text{OH})_2 + \text{CaSO}_4$
 In the presence of dissolved oxygen,
 (b) $2\text{Fe}(\text{OH})_2 + \text{H}_2\text{O} + \text{O} = 2\text{Fe}(\text{OH})_3$
5. Hypochlorite of lime in water:
 (a) $\text{Ca}(\text{OCl})_2 + \text{H}_2\text{O} + \text{CO}_2 = 2\text{HOCl} + \text{CaCO}_3$
 (b) $\text{HOCl} = \text{HCl} + \text{O}$
6. Chlorine in water:
 (a) $\text{Cl}_2 + \text{H}_2\text{O} = \text{HOCl} + \text{HCl}$
 (b) $\text{HOCl} = \text{HCl} + \text{O}$
7. Chlorine and ammonia in water:
 (a) $\text{Cl}_2 + \text{H}_2\text{O} = \text{HCl} + \text{HOCl}$
 (b) $\text{HOCl} + \text{NH}_3 = \text{NH}_2\text{Cl} + \text{H}_2\text{O}$ (at pH 8.5)
 (c) $2\text{HOCl} + \text{NH}_3 = \text{NHCl}_2 + 2\text{H}_2\text{O}$ (at pH 4.5)
 (d) $3\text{HOCl} + \text{NH}_3 = \text{NCl}_3 + 3\text{H}_2\text{O}$ (below pH 4.4)
8. Corrosion control:
 (1) $\text{Fe} + 2\text{HOH} = \text{Fe}(\text{OH})_2 + \text{H}_2$
 (1a) $\text{H}_2 + \text{O} = \text{H}_2\text{O}$
 (1b) $2\text{Fe}(\text{OH})_2 + \text{H}_2\text{O} + \text{O} = 2\text{Fe}(\text{OH})_3$
 (2) $\text{Fe} + 2\text{H}_2\text{CO}_3 = \text{Fe}(\text{HCO}_3)_2 + \text{H}_2$
 (2a) $\text{H}_2 + \text{O} = \text{H}_2\text{O}$
 (2b) $2\text{Fe}(\text{HCO}_3)_2 + \text{H}_2\text{O} + \text{O} = 2\text{Fe}(\text{OH})_3 + 4\text{CO}_2$

WATER-SOFTENING REACTIONS

9. Lime and carbon dioxide:
 (a) $\text{Ca}(\text{OH})_2 + 2\text{CO}_2 = \text{Ca}(\text{HCO}_3)_2$
 (b) $\text{Ca}(\text{OH})_2 + \text{H}_2\text{O} + \text{CO}_2 = \text{CaCO}_3 + 2\text{H}_2\text{O}$
10. Bicarbonate hardness and lime:

$$\text{Ca}(\text{HCO}_3)_2 + \text{Ca}(\text{OH})_2 = 2\text{CaCO}_3 + 2\text{H}_2\text{O}$$
11. Magnesium carbonate and lime:

$$\text{MgCO}_3 + \text{Ca}(\text{OH})_2 = \text{Mg}(\text{OH})_2 + \text{CaCO}_3$$
12. Magnesium sulfate and lime:

$$\text{MgSO}_4 + \text{Ca}(\text{OH})_2 = \text{Mg}(\text{OH})_2 + \text{CaSO}_4$$
13. Soda ash and calcium sulfate:

$$\text{CaSO}_4 + \text{Na}_2\text{CO}_3 = \text{CaCO}_3 + \text{Na}_2\text{SO}_4$$
14. Zeolite and hardness:
 Let Z represent zeolite:

$$2\text{NaZ} + \text{CaSO}_4 = \text{CaZ} + \text{Na}_2\text{SO}_4$$
15. Calcium zeolite and salt:

$$\text{CaZ} + 2\text{NaCl} = \text{NaZ} + \text{CaCl}_2$$

Table XIX. *Disinfecting water mains and reservoirs*

Quantity of chlorine compound required to provide a 50 parts per million concentration of chlorine per 100 feet of main

| Diameter of pipe (inches) | Gallons per 100 feet | 70 % calcium hypochlorite | 25 % chloride of lime |
|------------------------------|-------------------------|------------------------------|--------------------------|
| | | OUNCES | OUNCES |
| 2 | 16.4 | 0.2 | 0.5 |
| 4 | 65.5 | 1 | 2 |
| 6 | 147 | 2 | 4 |
| 8 | 261 | 4 | 7 |
| 10 | 408 | 6 | 11 |
| 12 | 588 | 6 | 16 |
| 16 | 1,044 | 10 | 28 |
| 18 | 1,325 | 13 | 35 |
| 20 | 1,632 | 16 | 44 |
| 24 | 2,352 | 23 | 63 |
| 30 | 3,672 | 35 | 98 |

Amount of hypochlorite required for disinfecting reservoirs
using 50 parts per million dosage

| Capacity (gallons) | 70 % hypo- chlorite | 25 % chloride of lime | Capacity (gallons) | 70 % hypo- chlorite | 25 % chloride of lime |
|-----------------------|------------------------|--------------------------|-----------------------|------------------------|--------------------------|
| | POUNDS | POUNDS | | POUNDS | POUNDS |
| 1,000 | 0.6 | 1.7 | 100,000 | 60 | 167 |
| 5,000 | 3 | 8.3 | 200,000 | 119 | 333 |
| 10,000 | 6 | 16.7 | 300,000 | 179 | 500 |
| 20,000 | 12 | 33.3 | 500,000 | 298 | 833 |
| 40,000 | 24 | 66.7 | 700,000 | 417 | 1,170 |
| 60,000 | 36 | 100 | 1,000,000 | 597 | 1,668 |
| 80,000 | 48 | 133 | 1,500,000 | 900 | 2,500 |

Table XX. Conversion factors

DISTANCE

| | | |
|---------|---------|-------------|
| Inch = | 2.54 | centimeters |
| Foot = | 30.48 | centimeters |
| Yard = | 91.44 | centimeters |
| Mile = | 5,280.0 | feet |
| Mile = | 1.609 | kilometers |
| Meter = | 3.28 | feet |
| Meter = | 39.37 | inches |

AREA

| | | |
|---------------|----------|--------------------|
| Square inch = | 6.45 | square centimeters |
| Square foot = | 144.0 | square inches |
| Acre = | 43,560.0 | square feet |
| Acre = | 4,047.0 | square meters |
| Square mile = | 640.0 | acres |

MASS

| | | |
|-----------------------|---------|-----------|
| Grain = | 0.0648 | grams |
| Ounce (avoirdupois) = | 437.5 | grains |
| Ounce = | 28.35 | grams |
| Ounce (Troy or av.) = | 480.0 | grains |
| Ounce (Troy) = | 31.1035 | grams |
| Pound (avoirdupois) = | 7,000.0 | grains |
| Pound = | 453.59 | grams |
| Pound (Troy) = | 5,760.0 | grains |
| Pound = | 373.24 | grams |
| Gram = | 15.4324 | grains |
| Kilogram = | 2.2046 | pounds av |

VOLUME

| | | |
|--------------------|---------|-------------------|
| Cubic inch = | 16.387 | cubic centimeters |
| Cubic foot = | 28,317 | cubic centimeters |
| Cubic foot = | 1,728.0 | cubic inches |
| Cubic foot = | 28.317 | liters |
| Cubic yard = | 27.0 | cubic feet |
| Cubic centimeter = | 0.99997 | milliliter |

LIQUID CAPACITY

| | | |
|-----------------|---------|---------------|
| * Fluid ounce = | 29.57 | milliliters |
| Pint = | 16.0 | fluid ounces |
| Pint = | 473.167 | milliliters |
| Pint = | 28.875 | cubic inches |
| Quart = | 0.946 | liter |
| Gallon = | 3.785 | liters |
| Gallon = | 231.0 | cubic inches |
| Milliliter = | 16.23 | minims |
| Milliliter = | 0.061 | cubic inch |
| Liter = | 1.0567 | liquid quarts |
| Liter = | 1,000.0 | milliliters |
| Liter = | 61.025 | cubic inches |
| Cubic inch = | 266 | minims |
| Cubic inch = | 16.387 | milliliters |

Table XX. Conversion factors (cont'd)

CONSTANTS AND EQUIVALENTS

| | | |
|------------------------------------|--|------------------------------------|
| Atmosphere = | 14.7 | pounds per square inch (sea level) |
| Pound per square inch = | 2.0376 | inches of mercury |
| Pound per square inch = | 2.307 | feet of water |
| Pound per square inch = | 27.71 | inches of water |
| Pound per square inch = | 0.0703 | kilogram per square centimeter |
| Foot of water = | 0.433 | pound per square inch |
| Inch of mercury = | 0.491 | pound per square inch |
| Inch of mercury = | 1.132 | feet of water |
| Horsepower = | 33,000.0 | foot-pounds per minute |
| Horsepower = | 0.746 | kilowatt |
| Water horsepower = | gallons per minute \times head in feet | |
| | 3,960 | |
| Kilowatt = | 1.3405 | horsepower |
| Efficiency = | water horsepower | |
| | brake horsepower | |
| Cubic foot of water weighs | 62.355 | pounds at 62° F. |
| Gallon of water weighs | 8.335 | pounds at 62° F. |
| U S gallon = | 3.785 | liters |
| Cubic foot of water = | 7.48 | U S gallons |
| Imperial gallon = | 1.2 | U S gallons |
| Velocity head $h = \frac{V^2}{2g}$ | | |
| $g =$ | 32.16 | feet per second per second |

MISCELLANEOUS DATA

| | | |
|--|-------------------------|------------|
| Railroad Tender Capacity—Normal | 5,000 gal—Maximum | 20,000 gal |
| Track Storage Tanks— | 25,000 to 50,000 | gal |
| Railroad Water Supply Points—Spacing— | 10 to 15 | miles |
| Tank Car Capacity—Standard Commercial— | 8,000 to 10,000 | gal |
| —Military | —5,000 | gal |
| Tank Truck Capacity—Military— | 1,500 gal (semitrailer) | |
| | 700 gal (truck) | |
| | 250 gal (trailer) | |

Table XXI. Flow of vertical jets in gallons per minute

| Height of jet (inches) | Diameter of pipe or hose (inches) | | | | Height of jet (inches) | Diameter of pipe or hose (inches) | | | |
|---------------------------|--------------------------------------|------|------|------|---------------------------|--------------------------------------|-------|------|-----|
| | 1 | 1½ | 2 | 3 | | 1 | 1½ | 2 | 3 |
| ½ | 3.96 | 8.9 | 15.6 | 35.6 | 15 | 22.0 | 49.5 | 87.8 | 198 |
| 1 | 5.60 | 12.6 | 22.4 | 50.4 | 20 | 25.4 | 57.2 | 102 | 228 |
| 2 | 7.99 | 18.0 | 32.0 | 71.9 | 30 | 30.9 | 69.5 | 123 | 278 |
| 4 | 11.3 | 25.4 | 45.3 | 102 | 60 | 43.8 | 98.6 | 175 | 394 |
| 6 | 13.9 | 31.3 | 55.5 | 125 | 108 | 58.9 | 132.5 | 236 | 531 |
| 8 | 16.0 | 36.0 | 64.0 | 144 | 144 | 68.0 | 153.0 | 272 | 612 |
| 10 | 17.9 | 40.3 | 71.6 | 161 | | | | | |

Table XXII. Flow of water from full-flowing horizontal jets

Note. Jet must be full-flowing; no contraction or enlargement.

$$\text{Flow in gpm} = 2.83 \cdot D^2 \cdot X$$

$$\sqrt{Y}$$

D = Inside diameter of pipe

X = Horizontal distance in inches

Y = Vertical distance in inches

Example using formula:

Given: A 3-inch-diameter standard pipe ($D = 3.07''$) held 16 inches from ground ($Y = 16''$). X determined by measurement ($X = 28''$).

$$2.83 \cdot 3.07^2 \cdot 28 = 2.83 \cdot 9.4 \cdot 28 = 187 \text{ gpm}$$

$$\sqrt{16} \quad 4$$

Note. Table below is based on $Y = 12''$. When table does not apply, measure Y at 9'', 16'', or 25'' for simplicity in taking square root.

Gpm for $Y = 12''$ and various values of X

| Distance $X =$ | 8" | 10" | 12" | 14" | 16" | 18" | 20" | 22" | 24" | 26" | 28" | 30" | 32" | 34" | 36" | 38" | 40" | 42" | 44" | 46" | 48" |
|--|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| $D = 1.61''$ $1\frac{1}{2}'' \phi$ Std pipe | 17 | 21 | 25 | 30 | 34 | 38 | 42 | 47 | 51 | 55 | 59 | 64 | 68 | 72 | 76 | 80 | 85 | 89 | 93 | 97 | 102 |
| $D = 2.07''$ $2'' \phi$ Std pipe | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 91 | 98 | 105 | 112 | 119 | 126 | 133 | 140 | 147 | 154 | 160 | 167 |
| $D = 4.03''$ $4'' \phi$ Std pipe | 106 | 132 | 159 | 185 | 212 | 238 | 265 | 291 | 318 | 344 | 371 | 397 | 424 | 450 | 477 | 503 | 530 | 556 | 583 | 609 | 656 |

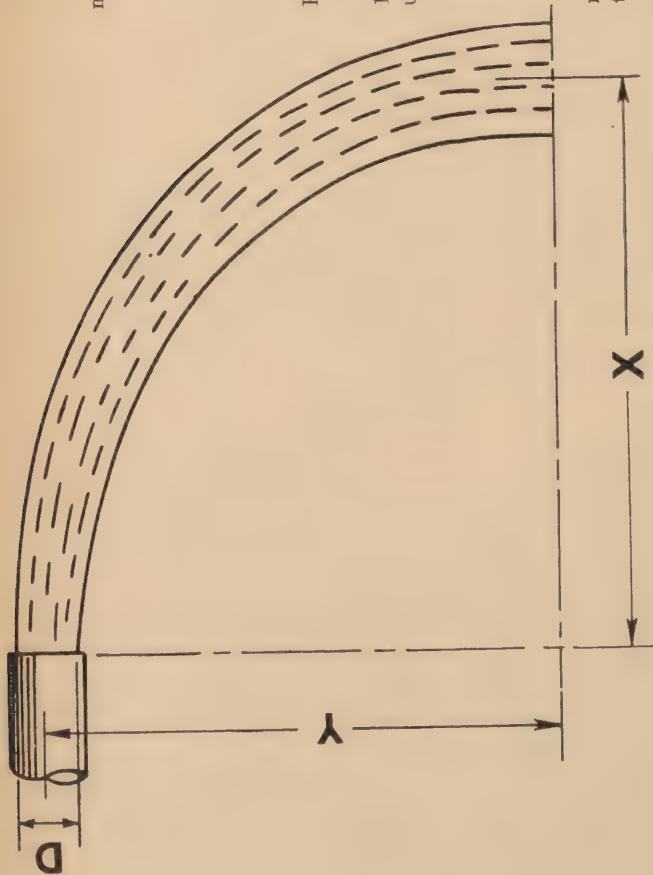
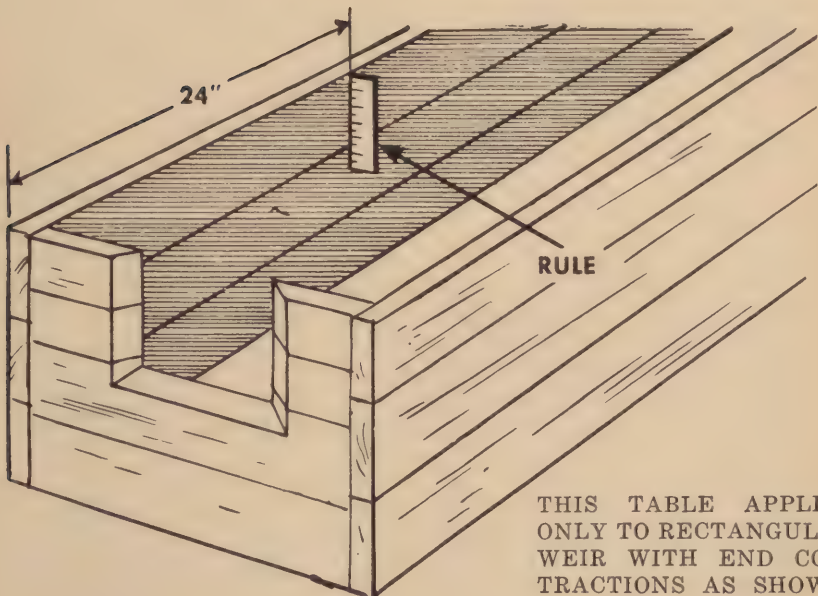


Table XXIII. Discharge over a rectangular weir per foot width

| Depth in inches | Gallons per minute | Depth in inches | Gallons per minute | Depth in inches | Gallons per minute |
|--------------------|-----------------------|--------------------|-----------------------|--------------------|-----------------------|
| 1 | 36 | 4 $\frac{3}{4}$ | 375 | 8 $\frac{1}{2}$ | 900 |
| 1 $\frac{1}{4}$ | 50 | 5 | 405 | 8 $\frac{3}{4}$ | 939 |
| 1 $\frac{1}{2}$ | 66 | 5 $\frac{1}{4}$ | 436 | 9 | 978 |
| 1 $\frac{3}{4}$ | 84 | 5 $\frac{1}{2}$ | 468 | 9 $\frac{1}{4}$ | 1,020 |
| 2 | 102 | 5 $\frac{3}{4}$ | 500 | 9 $\frac{1}{2}$ | 1,062 |
| 2 $\frac{1}{4}$ | 122 | 6 | 533 | 9 $\frac{3}{4}$ | 1,104 |
| 2 $\frac{1}{2}$ | 143 | 6 $\frac{1}{4}$ | 567 | 10 | 1,147 |
| 2 $\frac{3}{4}$ | 165 | 6 $\frac{1}{2}$ | 601 | 10 $\frac{1}{4}$ | 1,190 |
| 3 | 188 | 6 $\frac{3}{4}$ | 636 | 10 $\frac{1}{2}$ | 1,234 |
| 3 $\frac{1}{4}$ | 212 | 7 | 672 | 10 $\frac{3}{4}$ | 1,279 |
| 3 $\frac{1}{2}$ | 237 | 7 $\frac{1}{4}$ | 708 | 11 | 1,323 |
| 3 $\frac{3}{4}$ | 263 | 7 $\frac{1}{2}$ | 745 | 11 $\frac{1}{4}$ | 1,369 |
| 4 | 290 | 7 $\frac{3}{4}$ | 783 | 11 $\frac{1}{2}$ | 1,414 |
| 4 $\frac{1}{4}$ | 317 | 8 | 821 | 11 $\frac{3}{4}$ | 1,461 |
| 4 $\frac{1}{2}$ | 346 | 8 $\frac{1}{4}$ | 860 | 12 | 1,508 |

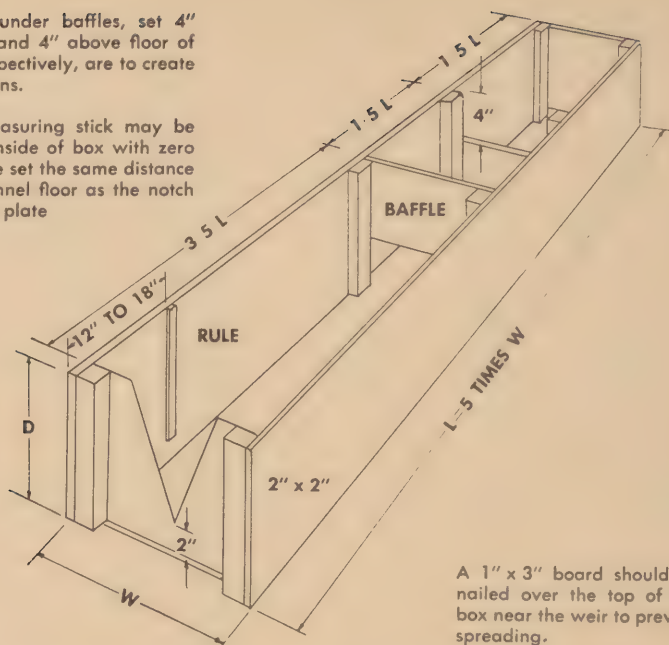
Note. Not accurate when depth of flow over weir exceeds $\frac{1}{3}$ width of weir.



NOTE:

Over and under baffles, set 4" below top and 4" above floor of channel respectively, are to create stilling basins.

Rule or measuring stick may be nailed on inside of box with zero point of rule set the same distance off the channel floor as the notch in the weir plate.

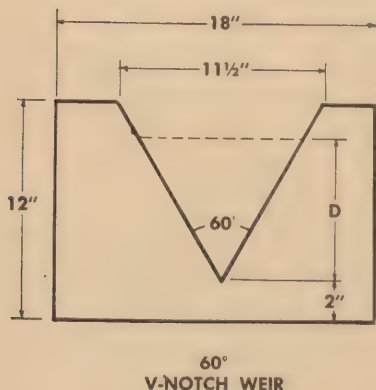


A 1" x 3" board should be nailed over the top of the box near the weir to prevent spreading.

The box should be constructed of 1" lumber and all cracks be made watertight. The underflow baffle could be made so that it could be adjusted in height off of the floor as needed to prevent disturbance of the water surface at the weir. The weir plate should be heavy-gage metal backed with 1" lumber.

Care should be taken to shore up the box so that the weight of the water will not cause structural failure. 2" x 4" timbers could be nailed to the under side of the box with the ends extending to be used as handles.

The structure should be carefully leveled both ways before taking depth-of-flow readings. The box should be filled with water to same elevation as notch in weir. The zero end of measuring rule should touch water surface.



FLOW IN GPM PER 1/4" OF DEPTH

| D | GPM | D | GPM |
|-------|-------|-------|-------|
| 1/2 | 0.25 | 4 1/2 | 57.9 |
| 3/4 | 0.69 | 4 3/4 | 66.2 |
| 1 | 1.41 | 5 | 75.2 |
| 1 1/4 | 2.45 | 5 1/4 | 84.7 |
| 1 1/2 | 3.84 | 5 1/2 | 95.1 |
| 1 3/4 | 5.61 | 5 3/4 | 106.1 |
| 2 | 7.84 | 6 | 117.9 |
| 2 1/4 | 10.45 | 6 1/4 | 130.3 |
| 2 1/2 | 13.60 | 6 1/2 | 143.7 |
| 2 3/4 | 17.17 | 6 3/4 | 157.6 |
| 3 | 21.29 | 7 | 172.4 |
| 3 1/4 | 25.92 | 7 1/4 | 188.1 |
| 3 1/2 | 31.15 | 7 1/2 | 204.4 |
| 3 3/4 | 36.89 | 7 3/4 | 221.8 |
| 4 | 43.31 | 8 | 239.7 |
| 4 1/4 | 50.27 | | |

Figure 179. Measuring flow of water in a 60° V-notch weir.

Table XXIV. Rate of flow equivalents

| Units | Cubic feet per second | Cubic feet per minute | U.S. gallons per minute | U.S. gallons per 24 hours | British Imperial gallons per minute | Liters per minute | Acre-feet per hour | Acre-feet per 24 hours |
|--------------------------------------|--------------------------|------------------------|-------------------------|---------------------------|-------------------------------------|-------------------|------------------------|------------------------|
| 1 cubic foot per second | = 1.0 | 60.0 | 448.831 | 646.317.0 | 373.729 | 1,698.98 | 0.082645 | 1.98347 |
| 1 cubic foot per minute | = 0.016667 | 1.0 | 7.48052 | 10,771.9 | 6.22882 | 28.3163 | 0.0013774 | 0.033058 |
| 1 U.S. gallon per minute | = 0.0022280 | 0.13368 | 1.0 | 1,440.0 | 0.83267 | 3.78533 | 0.0001841 | 0.0044192 |
| 1 U.S. gallon per 24 hours | = 1.547×10^{-6} | 9.283×10^{-5} | 0.0006944 | 1.0 | 0.0005782 | 0.0026287 | 1.279×10^{-7} | 3.069×10^{-6} |
| 1 British Imperial gallon per minute | = 0.0026757 | 0.16054 | 1.20095 | 1,729.37 | 1.0 | 4.54601 | 0.0002211 | 0.0053072 |
| 1 liter per minute | = 0.0005886 | 0.035315 | 0.26418 | 380.416 | 0.21997 | 1.0 | 4.864×10^{-5} | 0.001167 |
| 1 acre-foot per hour | = 12.1 | 726.0 | 5,430.86 | 7,820.434.0 | 4,522.13 | 20,557.6 | 1.0 | 24.0 |
| 1 acre-foot per 24 hours | = 0.50417 | 30.25 | 226.286 | 325.851.0 | 188.422 | 856.567 | 0.041667 | 1.0 |

Table XXV. Volume and capacity equivalents

| Units | U.S. gallons | British Imperial gallons | Liters | Cubic feet | Cubic inches | Acre-foot |
|---------------------------------------|--------------------------|--------------------------|--------------|------------------------|-----------------|------------------------|
| 1 U.S. gallon | = 1.0 | 0.832672 | 3.78533 | 0.133681 | 231.0 | 3.069×10^{-6} |
| 1 British Imperial gallon | = 1.20095 | 1.0 | 4.54601 | 0.160544 | 277.420 | 3.686×10^{-6} |
| 1 liter | = 0.264177 | 0.219973 | 1.0 | 0.035315 | 61.0250 | 8.107×10^{-7} |
| 1 cubic foot | = 7.48052 | 6.22882 | 28.3163 | 1.0 | 1,728.0 | 2.296×10^{-5} |
| 1 cubic inch | = 4.329×10^{-3} | 3.605×10^{-3} | 0.016387 | 5.787×10^{-4} | 1.0 | 1.329×10^{-8} |
| 1 acre-foot | = 325851.0 | 271,328.0 | 1,233,456.0 | 43,560.0 | 75,271,680.0 | 1.0 |
| 1 inch deep on 1 acre | = 27154.3 | 22,610.6 | 102,788.0 | 3,630.0 | 6,272,640.0 | 0.083333 |
| 1 inch deep on 1 square mile | = 17,378,743.0 | 14,470,801.0 | 65,784,344.0 | 2,323,200.0 | 4,014,489,600.0 | 53.3333 |
| 1 meter deep on 1 hectare | = 2,641,705.0 | 2,199,675.0 | 9,999,734.0 | 353,145.0 | 610,233,780.0 | 8.10708 |
| 1 centimeter deep on 1 square meter | = 2.64171 | 2.19967 | 9.99973 | 0.353145 | 610.234 | 8.107×10^{-6} |
| 1 pound of water at 39.2° F | = 0.11983 | 0.099778 | 0.45359 | 0.016019 | 27.6805 | 3.677×10^{-7} |
| 1 pound of water at 50° F | = 0.11986 | 0.099806 | 0.45372 | 0.016023 | 27.6880 | 3.678×10^{-7} |
| 1 pound of water at 62° F | = 0.11997 | 0.099892 | 0.45411 | 0.016037 | 27.7121 | 3.682×10^{-7} |
| 1 U.S. gallon per minute for 24 hours | = 1,440.0 | 1,199.05 | 5,450.88 | 192.5 | 332,640.0 | 0.0044192 |
| 1 cubic foot per minute for 24 hours | = 10,771.9 | 8,969.50 | 40,775.4 | 1,440.0 | 2,488,320.0 | 0.033058 |

Table XXVI. Pressure equivalents

| Units | Pounds per square inch | Pounds per square foot | Kilograms per square centimeter | Inches of mercury at 32° F. | Feet of water at 39.2° F. | Feet of water at 62° F. | Atmospheres |
|----------------------------------|------------------------------|------------------------------|---------------------------------------|-----------------------------------|---------------------------------|-------------------------------|------------------------|
| 1 pound per square inch | 1.0 | 144.0 | 0.0703067 | 2.0360 | 2.30671 | 2.30934 | 0.068044 |
| 1 pound per square foot | 0.0069444 | 1.0 | 0.0004882 | 0.014139 | 0.016019 | 0.016037 | 0.0004725 |
| 1 ounce per square inch | 0.0625 | 9.0 | 0.0043942 | 0.12725 | 0.144169 | 0.144334 | 0.0042528 |
| 1 kilogram per square centimeter | 14.2234 | 2,048.17 | 1.0 | 28.9582 | 32.8092 | 32.8467 | 0.967820 |
| 1 kilogram per square meter | 0.0014223 | 0.204817 | 0.0001 | 0.0028958 | 0.0032809 | 0.0032847 | 9.678×10^{-5} |
| 1 inch of mercury at 32° F. | 0.49117 | 70.7285 | 0.034533 | 1.0 | 1.13299 | 1.13428 | 0.033421 |
| 1 inch of water at 39.2° F. | 0.036127 | 5.20222 | 0.0025399 | 0.073552 | 0.083333 | 0.083428 | 0.0024582 |
| 1 inch of water at 62° F. | 0.036085 | 5.19628 | 0.0025370 | 0.073468 | 0.083238 | 0.083333 | 0.0024554 |
| 1 foot of water at 39.2° F. | 0.43352 | 62.4266 | 0.030479 | 0.88262 | 1.0 | 1.00114 | 0.029498 |
| 1 foot of water at 62° F. | 0.43302 | 62.3554 | 0.030444 | 0.88162 | 0.99886 | 1.0 | 0.029465 |
| 1 atmosphere | 14.6963 | 2,116.27 | 1.03325 | 29.9210 | 33.9001 | 33.9388 | 1.0 |

Table XXVII. For conversion of pressure in pounds per square inch to head of water in vertical feet

| Pressure in psi | Head in feet | Pressure in psi | Head in feet | Pressure in psi | Head in feet |
|-----------------|--------------|-----------------|--------------|-----------------|--------------|
| 0.1 | .23 | 41 | 94.7 | 91 | 210 |
| 0.2 | .46 | 42 | 97.0 | 92 | 213 |
| 0.3 | .69 | 43 | 99.3 | 93 | 215 |
| 0.4 | .92 | 44 | 102.0 | 94 | 217 |
| | | 45 | 104.0 | 95 | 219 |
| 0.5 | 1.16 | 46 | 106.0 | 96 | 222 |
| 0.6 | 1.39 | 47 | 109.0 | 97 | 224 |
| 0.7 | 1.62 | 48 | 111.0 | 98 | 226 |
| 0.8 | 1.85 | 49 | 113.0 | 99 | 229 |
| 0.9 | 2.08 | 50 | 116.0 | 100 | 231 |
| 1.0 | 2.31 | 51 | 118.0 | 102 | 236 |
| 2.0 | 4.62 | 52 | 120.0 | 104 | 240 |
| 3.0 | 6.93 | 53 | 122.0 | 106 | 245 |
| 4.0 | 9.23 | 54 | 125.0 | 108 | 249 |
| 5.0 | 11.6 | 55 | 127.0 | 110 | 254 |
| 6.0 | 13.9 | 56 | 129.0 | 112 | 259 |
| 7.0 | 16.2 | 57 | 132.0 | 114 | 263 |
| 8.0 | 18.5 | 58 | 134. | 116 | 268 |
| 9.0 | 20.8 | 59 | 136.0 | 118 | 273 |
| 10.0 | 23.1 | 60 | 139.0 | 120 | 277 |
| 11.0 | 25.4 | 61 | 141.0 | 122 | 282 |
| 12.0 | 27.7 | 62 | 143.0 | 124 | 286 |
| 13.0 | 30.0 | 63 | 146.0 | 126 | 291 |
| 14.0 | 32.3 | 64 | 148.0 | 128 | 296 |
| 15.0 | 34.7 | 65 | 150.0 | 130 | 300 |
| 16.0 | 37.0 | 66 | 153.0 | 132 | 305 |
| 17.0 | 39.3 | 67 | 155.0 | 134 | 310 |
| 18.0 | 41.6 | 68 | 157.0 | 136 | 314 |
| 19.0 | 43.9 | 69 | 159.0 | 138 | 319 |
| 20.0 | 46.2 | 70 | 162.0 | 140 | 323 |
| 21.0 | 48.5 | 71 | 164.0 | 142 | 328 |
| 22.0 | 50.8 | 72 | 166.0 | 144 | 333 |
| 23.0 | 53.1 | 73 | 169.0 | 146 | 337 |
| 24.0 | 55.4 | 74 | 171.0 | 148 | 342 |
| 25.0 | 57.8 | 75 | 173.0 | 150 | 347 |
| 26.0 | 60.1 | 76 | 176.0 | 155 | 358 |
| 27.0 | 62.4 | 77 | 178.0 | 160 | 370 |
| 28.0 | 64.9 | 78 | 180.0 | 165 | 381 |
| 29.0 | 67.0 | 79 | 183.0 | 170 | 393 |
| 30.0 | 69.3 | 80 | 185.0 | 175 | 404 |
| 31.0 | 71.6 | 81 | 187.0 | 180 | 416 |
| 32.0 | 73.9 | 82 | 189.0 | 185 | 427 |
| 33.0 | 76.2 | 83 | 192.0 | 190 | 439 |
| 34.0 | 78.5 | 84 | 194.0 | 195 | 450 |
| 35.0 | 80.9 | 85 | 196.0 | 200 | 462 |
| 36.0 | 83.2 | 86 | 199.0 | 220 | 508 |
| 37.0 | 85.5 | 87 | 201.0 | 240 | 554 |
| 38.0 | 87.8 | 88 | 203.0 | 260 | 601 |
| 39.0 | 90.1 | 89 | 206.0 | 280 | 647 |
| 40.0 | 92.4 | 90 | 208.0 | 300 | 693 |

Table XXVIII. For conversion of head of water in vertical feet to pressure in pounds per square inch

| Head in feet | Pressure in psi | Head in feet | Pressure in psi | Head in feet | Pressure in psi |
|--------------|-----------------|--------------|-----------------|--------------|-----------------|
| 1 | .43 | 52 | 22.5 | 204 | 88.4 |
| 2 | .86 | 54 | 23.4 | 208 | 90.1 |
| 3 | 1.30 | 56 | 24.3 | 212 | 91.8 |
| 4 | 1.73 | 58 | 25.1 | 216 | 93.6 |
| 5 | 2.16 | 60 | 26.0 | 220 | 95.3 |
| 6 | 2.59 | 62 | 26.9 | 224 | 97.0 |
| 7 | 3.03 | 64 | 27.7 | 228 | 98.8 |
| 8 | 3.46 | 66 | 28.6 | 232 | 100.0 |
| 9 | 3.89 | 68 | 29.5 | 236 | 102.0 |
| 10 | 4.33 | 70 | 30.3 | 240 | 104.0 |
| 11 | 4.76 | 72 | 31.2 | 244 | 106.0 |
| 12 | 5.20 | 74 | 32.1 | 248 | 107.0 |
| 13 | 5.63 | 76 | 32.9 | 252 | 109.0 |
| 14 | 6.06 | 78 | 33.8 | 256 | 111.0 |
| 15 | 6.49 | 80 | 34.7 | 260 | 113.0 |
| 16 | 6.93 | 82 | 35.5 | 264 | 114.0 |
| 17 | 7.36 | 84 | 36.4 | 268 | 116.0 |
| 18 | 7.79 | 86 | 37.3 | 272 | 118.0 |
| 19 | 8.22 | 88 | 38.1 | 276 | 120.0 |
| 20 | 8.66 | 90 | 39.0 | 280 | 121.0 |
| 21 | 9.09 | 92 | 39.9 | 284 | 123.0 |
| 22 | 9.53 | 94 | 40.7 | 288 | 125.0 |
| 23 | 10.0 | 96 | 41.6 | 292 | 126.0 |
| 24 | 10.4 | 98 | 42.5 | 296 | 128.0 |
| 25 | 10.8 | 100 | 43.3 | 300 | 130.0 |
| 26 | 11.3 | 104 | 45.1 | 310 | 134.0 |
| 27 | 11.7 | 108 | 46.8 | 320 | 139.0 |
| 28 | 12.1 | 112 | 48.5 | 330 | 143.0 |
| 29 | 12.6 | 116 | 50.2 | 340 | 147.0 |
| 30 | 13.0 | 120 | 52.0 | 350 | 152.0 |
| 31 | 13.4 | 124 | 53.7 | 360 | 156.0 |
| 32 | 13.9 | 128 | 55.4 | 370 | 160.0 |
| 33 | 14.3 | 132 | 57.2 | 380 | 165.0 |
| 34 | 14.7 | 136 | 58.9 | 390 | 169.0 |
| 35 | 15.2 | 140 | 60.6 | 400 | 173.0 |
| 36 | 15.6 | 144 | 62.4 | 420 | 182.0 |
| 37 | 16.0 | 148 | 64.1 | 440 | 191.0 |
| 38 | 16.5 | 152 | 65.8 | 460 | 199.0 |
| 39 | 16.9 | 156 | 67.6 | 480 | 208.0 |
| 40 | 17.3 | 160 | 69.3 | 500 | 217.0 |
| 41 | 17.8 | 164 | 71.0 | 520 | 225.0 |
| 42 | 18.2 | 168 | 72.8 | 540 | 234.0 |
| 43 | 18.6 | 172 | 74.5 | 560 | 242.0 |
| 44 | 19.1 | 176 | 76.2 | 580 | 251.0 |
| 45 | 19.5 | 180 | 78.0 | 600 | 260.0 |
| 46 | 19.9 | 184 | 79.7 | 650 | 282.0 |
| 47 | 20.4 | 188 | 81.4 | 700 | 303.0 |
| 48 | 20.8 | 192 | 83.2 | 800 | 347.0 |
| 49 | 21.2 | 196 | 84.9 | 900 | 390.0 |
| 50 | 21.7 | 200 | 86.6 | 1.000 | 433.0 |

Table XXIX. Friction of water in pipes

The friction head losses in pipes were derived using the William & Hazen coefficient of 100. This coefficient corresponds to 10-year-old steel or 18-year-old cast-iron pipe. To adjust the friction head loss for various types of pipe, use the factor below. For example: To find the friction head loss for *3-inch iron pipe with very rough inside surface*, passing 50 gpm, find 13.8 feet per 1,000 feet of pipe in table and multiply by 2.58. Answer: 35.6 feet friction head loss per 1,000 feet of *3-inch iron pipe with very rough inside surface*.

| Kind of pipe: | Factor |
|--|--------|
| New cast iron (straight) | .540 |
| New lead or brass | .540 |
| New concrete or masonry (very smooth) | .540 |
| New cast iron (not straight) | .615 |
| Smooth concrete or masonry | .615 |
| New wrought iron (smooth) | .715 |
| Cast iron (5 years old) | .715 |
| Wood (smooth) | .715 |
| New rivet steel | .840 |
| Vitrified sewer | .840 |
| Cast iron (30 years old) | 1.51 |
| Old wrought iron | 1.51 |
| Small wrought iron (over 15 years old) | 1.51 |
| Iron with very rough inside surface | 2.58 |

| Gallons per minute | Gallons per 24 hours | Velocity feet per second | Velocity head in feet | Friction in feet per 1,000 feet of pipe |
|--------------------------|----------------------------|--------------------------------|-----------------------------|---|
|--------------------------|----------------------------|--------------------------------|-----------------------------|---|

 $\frac{1}{2}$ -inch pipe (0.623 inch inside dia)

| | | | | |
|----|--------|-------|------|---------|
| 1 | 1,440 | 1.05 | 0.02 | 21.0 |
| 2 | 2,880 | 2.10 | 0.07 | 74.0 |
| 3 | 4,320 | 3.16 | 0.16 | 158.0 |
| 4 | 5,760 | 4.21 | 0.28 | 270.0 |
| 5 | 7,200 | 5.26 | 0.43 | 410.0 |
| 6 | 8,640 | 6.31 | 0.61 | 570.0 |
| 7 | 10,080 | 7.37 | 0.84 | 760.0 |
| 8 | 11,520 | 8.42 | 1.10 | 980.0 |
| 9 | 12,960 | 9.47 | 1.40 | 1,210.0 |
| 10 | 14,400 | 10.52 | 1.70 | 1,470.0 |

 $\frac{3}{4}$ -inch pipe (0.824 inch inside dia)

| | | | | |
|----|--------|-------|------|---------|
| 2 | 2,880 | 1.20 | 0.02 | 19.0 |
| 3 | 4,320 | 1.80 | 0.05 | 41.0 |
| 4 | 5,760 | 2.41 | 0.09 | 70.0 |
| 5 | 7,200 | 3.01 | 0.15 | 105.0 |
| 6 | 8,640 | 3.61 | 0.20 | 147.0 |
| 8 | 11,520 | 4.81 | 0.37 | 250.0 |
| 10 | 14,400 | 6.02 | 0.56 | 380.0 |
| 12 | 17,280 | 7.22 | 0.80 | 530.0 |
| 15 | 21,600 | 9.02 | 1.26 | 800.0 |
| 20 | 28,800 | 12.03 | 2.24 | 1,360.0 |

| Gallons per minute | Gallons per 24 hours | Velocity feet per second | Velocity head in feet | Friction in feet per 1,000 feet of pipe |
|---------------------------------------|----------------------------|--------------------------------|-----------------------------|---|
| 1-inch pipe (1.048 inches inside dia) | | | | |
| 3 | 4,320 | 1.12 | 0.02 | 12.6 |
| 4 | 5,760 | 1.49 | 0.03 | 21.4 |
| 5 | 7,200 | 1.86 | 0.05 | 32.5 |
| 6 | 8,640 | 2.23 | 0.07 | 45.5 |
| 8 | 11,520 | 2.98 | 0.14 | 78.0 |
| 10 | 14,400 | 3.72 | 0.22 | 117.0 |
| 12 | 17,280 | 4.46 | 0.30 | 164.0 |
| 14 | 20,160 | 5.20 | 0.45 | 220.0 |
| 16 | 23,040 | 5.95 | 0.55 | 280.0 |
| 18 | 25,920 | 6.69 | 0.70 | 350.0 |
| 20 | 28,800 | 7.44 | 0.87 | 420.0 |
| 25 | 36,000 | 9.30 | 1.34 | 640.0 |
| 30 | 43,200 | 11.15 | 1.93 | 890.0 |
| 35 | 50,400 | 13.02 | 2.65 | 1,190.0 |
| 40 | 57,600 | 14.88 | 3.42 | 1,520.0 |

| | | | | |
|---------------------------------------|--------|-------|------|---------|
| 1½-inch pipe (1.61 inches inside dia) | | | | |
| 4 | .00576 | 0.63 | 0.01 | 2.6 |
| 6 | .00864 | 0.94 | 0.01 | 5.6 |
| 8 | .0115 | 1.26 | 0.02 | 9.5 |
| 10 | .0144 | 1.57 | 0.04 | 14.3 |
| 12 | .01728 | 1.89 | 0.05 | 20.1 |
| 14 | .0202 | 2.20 | 0.06 | 26.8 |
| 16 | .0230 | 2.52 | 0.10 | 34.1 |
| 20 | .0288 | 3.15 | 0.15 | 52.0 |
| 25 | .0360 | 3.96 | 0.24 | 78.0 |
| 30 | .0432 | 4.72 | 0.38 | 110.0 |
| 35 | .0504 | 5.51 | 0.47 | 147.0 |
| 40 | .0576 | 6.30 | 0.61 | 188.0 |
| 45 | .0648 | 7.08 | 0.77 | 232.0 |
| 50 | .0720 | 7.87 | 0.97 | 284.0 |
| 60 | .0864 | 9.44 | 1.38 | 396.0 |
| 70 | .101 | 11.02 | 1.87 | 530.0 |
| 80 | .115 | 12.59 | 2.48 | 680.0 |
| 90 | .130 | 14.17 | 3.12 | 840.0 |
| 100 | .144 | 15.74 | 3.84 | 1,020.0 |
| 120 | .173 | 18.89 | 5.51 | 1,430.0 |
| 140 | .202 | 22.04 | 7.60 | 1,900.0 |

| | | | | |
|--------------------------------------|--------|------|------|------|
| 2-inch pipe (2.00 inches inside dia) | | | | |
| 6 | .00864 | 0.61 | 0.01 | 2.0 |
| 10 | .0144 | 1.02 | 0.02 | 5.0 |
| 15 | .0216 | 1.54 | 0.04 | 10.8 |
| 20 | .288 | 2.04 | 0.06 | 18.2 |
| 25 | .0360 | 2.55 | 0.10 | 27.3 |

| Gallons per minute | Millions of gallons per 24 hours | Velocity feet per second | Velocity head in feet | Friction in feet per 1,000 feet of pipe |
|--------------------------|--|--------------------------------|-----------------------------|---|
| 2-inch pipe cont'd | | | | |
| 30 | .0432 | 3.06 | 0.15 | 38.4 |
| 35 | .0504 | 3.57 | 0.20 | 51.0 |
| 40 | .0576 | 4.08 | 0.26 | 66.0 |
| 50 | .0720 | 5.11 | 0.40 | 99.0 |
| 60 | .0864 | 6.13 | 0.58 | 139.0 |
| 70 | .101 | 7.15 | 0.79 | 184.0 |
| 80 | .115 | 8.17 | 1.04 | 237.0 |
| 90 | .130 | 9.19 | 1.31 | 294.0 |
| 100 | .144 | 10.21 | 1.62 | 358.0 |
| 120 | .173 | 12.25 | 2.33 | 500.0 |
| 140 | .202 | 14.30 | 3.17 | 670.0 |
| 160 | .230 | 16.34 | 4.14 | 860.0 |
| 180 | .259 | 18.38 | 5.23 | 1070.0 |
| 200 | .288 | 20.42 | 6.46 | 1290.0 |
| 220 | .316 | 22.47 | 7.82 | 1540.0 |
| 240 | .345 | 24.51 | 9.31 | 1,820.0 |
| 260 | .374 | 26.55 | 10.90 | 2,110.0 |
| 3-inch pipe | | | | |
| 10 | .01440 | .45 | 0.00 | 0.7 |
| 15 | .02160 | .68 | 0.01 | 1.5 |
| 20 | .02880 | .91 | 0.01 | 2.5 |
| 30 | .04320 | 1.36 | 0.03 | 5.4 |
| 40 | .05760 | 1.82 | 0.05 | 9.1 |
| 50 | .07200 | 2.27 | 0.08 | 13.8 |
| 60 | .08640 | 2.72 | 0.12 | 19.2 |
| 70 | .10080 | 3.18 | 0.16 | 25.7 |
| 90 | .11520 | 3.63 | 0.20 | 32.8 |
| 80 | .12960 | 4.09 | 0.26 | 40.8 |
| 100 | .14400 | 4.54 | 0.32 | 49.6 |
| 120 | .17280 | 5.45 | 0.46 | 70.0 |
| 140 | .20160 | 6.35 | 0.63 | 92.0 |
| 160 | .23040 | 7.26 | 0.82 | 118.0 |
| 180 | .25920 | 8.17 | 1.04 | 148.0 |
| 200 | .28800 | 9.08 | 1.28 | 178.0 |
| 220 | .31680 | 9.99 | 1.55 | 213.0 |
| 240 | .34560 | 10.89 | 1.84 | 251.0 |
| 260 | .37440 | 11.80 | 2.16 | 291.0 |
| 280 | .40320 | 12.71 | 2.51 | 334.0 |
| 300 | .43200 | 13.62 | 2.88 | 380.0 |
| 320 | .46080 | 14.52 | 3.28 | 428.0 |
| 340 | .48960 | 15.43 | 3.71 | 479.0 |
| 360 | .51840 | 16.34 | 4.15 | 530.0 |
| 380 | .54720 | 17.25 | 4.62 | 590.0 |
| 400 | .57600 | 18.16 | 5.11 | 650.0 |
| 420 | .60480 | 19.06 | 5.64 | 710.0 |
| 440 | .63360 | 19.97 | 6.20 | 770.0 |
| 460 | .66240 | 20.88 | 6.78 | 840.0 |
| 480 | .69120 | 21.79 | 7.38 | 910.0 |
| 500 | .72000 | 22.70 | 8.00 | 980.0 |
| 550 | .79200 | 24.96 | 9.70 | 1170.0 |
| 600 | .86400 | 27.23 | 11.50 | 1370.0 |

| Gallons per minute | Millions of gallons per 24 hours | Velocity feet per second | Velocity head in feet | Friction in feet per 1,000 feet of pipe |
|--------------------------|--|--------------------------------|-----------------------------|---|
| 4-inch pipe | | | | |
| 20 | .02880 | 0.51 | 0.00 | .62 |
| 30 | .04320 | 0.77 | 0.01 | 1.32 |
| 40 | .05760 | 1.02 | 0.02 | 2.23 |
| 50 | .07200 | 1.28 | 0.03 | 3.39 |
| 60 | .08640 | 1.53 | 0.04 | 4.72 |
| 70 | .10080 | 1.79 | 0.05 | 6.3 |
| 80 | .11520 | 2.04 | 0.06 | 8.1 |
| 100 | .14400 | 2.55 | 0.10 | 12.2 |
| 120 | .17280 | 3.06 | 0.15 | 17.1 |
| 140 | .20160 | 3.57 | 0.20 | 22.8 |
| 160 | .23040 | 4.08 | 0.26 | 29.1 |
| 180 | .25920 | 4.60 | 0.33 | 36.1 |
| 200 | .28800 | 5.11 | 0.41 | 44.0 |
| 220 | .31680 | 5.62 | 0.49 | 52.0 |
| 240 | .34560 | 6.13 | 0.58 | 62.0 |
| 260 | .37440 | 6.64 | 0.69 | 72.0 |
| 280 | .40320 | 7.15 | 0.79 | 82.0 |
| 300 | .43300 | 7.66 | 0.91 | 93.0 |
| 320 | .46080 | 8.17 | 1.04 | 105.0 |
| 340 | .48960 | 8.68 | 1.17 | 117.0 |
| 360 | .51840 | 9.19 | 1.31 | 131.0 |
| 400 | .57600 | 10.21 | 1.62 | 160.0 |
| 450 | .64800 | 11.49 | 2.05 | 198.0 |
| 500 | .72000 | 12.77 | 2.53 | 240.0 |
| 600 | .86400 | 15.32 | 3.65 | 337.0 |
| 700 | 1.00800 | 17.87 | 4.96 | 449.0 |
| 800 | 1.15200 | 20.42 | 6.48 | 570.0 |
| 900 | 1.29600 | 22.98 | 8.20 | 710.0 |

| | | | | |
|-------------|-------|-------|------|-------|
| 6-inch pipe | | | | |
| 35 | .050 | 0.39 | 0.00 | .25 |
| 50 | .072 | 0.57 | 0.00 | .47 |
| 100 | .144 | 1.14 | 0.02 | 1.4 |
| 150 | .216 | 1.71 | 0.05 | 3.2 |
| 200 | .288 | 2.28 | 0.08 | 6.2 |
| 250 | .360 | 2.80 | 0.12 | 9.2 |
| 300 | .432 | 3.40 | 0.18 | 12.9 |
| 350 | .504 | 3.98 | 0.24 | 17.5 |
| 400 | .576 | 4.54 | 0.32 | 22.1 |
| 450 | .648 | 5.12 | 0.41 | 26.5 |
| 500 | .720 | 5.60 | 0.49 | 33.0 |
| 550 | .792 | 6.16 | 0.59 | 39.3 |
| 600 | .864 | 6.72 | 0.70 | 47.0 |
| 650 | .936 | 7.28 | 0.82 | 54.0 |
| 700 | 1.008 | 7.84 | 0.96 | 62.0 |
| 750 | 1.080 | 8.50 | 1.13 | 70.0 |
| 800 | 1.152 | 9.08 | 1.28 | 80.0 |
| 850 | 1.224 | 9.58 | 1.42 | 89.5 |
| 900 | 1.296 | 10.30 | 1.64 | 101.1 |
| 1,000 | 1.440 | 11.32 | 1.99 | 120.4 |
| 1,100 | 1.584 | 12.50 | 2.44 | 143.1 |
| 1,200 | 1.728 | 13.52 | 2.86 | 166.9 |
| 1,300 | 1.872 | 14.7 | 3.4 | 202.0 |
| 1,400 | 2.016 | 16.0 | 3.97 | 225.0 |
| 1,500 | 2.160 | 17.0 | 4.54 | 259.0 |

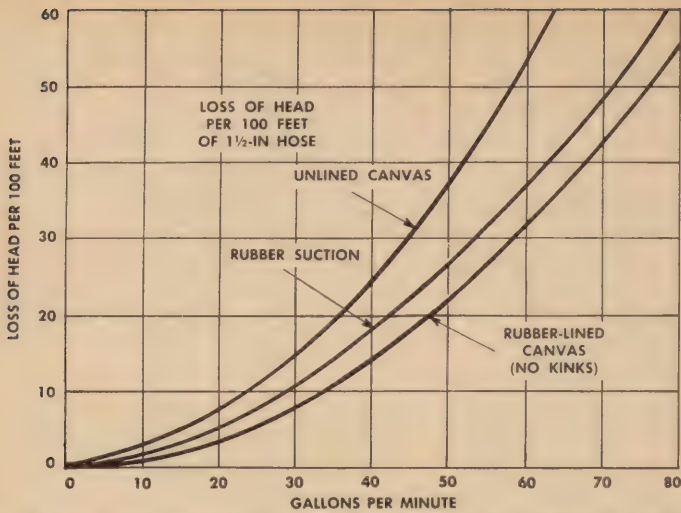


Figure 180. Curve showing loss of head per 100 feet of 1 1/2-inch hose.

Table XXXI. Tank capacities

(Areas and capacities per 1 foot of depth for vertical cylindrical tanks 1 foot to 100 feet in diameter)

| Diameter | Area in sq ft Cu ft per 1' of depth | U S gallons per 1' of depth | Diameter | Area in sq ft Cu ft per 1' of depth | U S gallons per 1' of depth |
|----------|---|--------------------------------|----------|---|--------------------------------|
| 1' | 0.785 | 5.87 | 3' 8" | 10.56 | 78.99 |
| 1' 1" | 0.922 | 6.89 | 3' 9" | 11.04 | 82.62 |
| 1' 2" | 1.069 | 8.00 | 3' 10" | 11.54 | 86.33 |
| 1' 3" | 1.227 | 9.18 | 3' 11" | 12.05 | 90.13 |
| 1' 4" | 1.396 | 10.44 | 4' | 12.57 | 94.00 |
| 1' 5" | 1.576 | 11.79 | 4' 1" | 13.10 | 97.96 |
| 1' 6" | 1.767 | 13.22 | 4' 2" | 13.64 | 102.0 |
| 1' 7" | 1.969 | 14.73 | 4' 3" | 14.19 | 106.1 |
| 1' 8" | 2.182 | 16.32 | 4' 4" | 14.75 | 110.3 |
| 1' 9" | 2.405 | 17.99 | 4' 5" | 15.32 | 114.6 |
| 1' 10" | 2.640 | 19.75 | 4' 6" | 15.90 | 119.0 |
| 1' 11" | 2.885 | 21.58 | 4' 7" | 16.50 | 123.4 |
| 2' | 3.142 | 23.50 | 4' 8" | 17.10 | 128.0 |
| 2' 1" | 3.409 | 25.50 | 4' 9" | 17.72 | 132.6 |
| 2' 2" | 3.687 | 27.58 | 4' 10" | 18.35 | 137.3 |
| 2' 3" | 3.976 | 29.74 | 4' 11" | 18.99 | 142.0 |
| 2' 4" | 4.276 | 31.99 | 5' | 19.63 | 146.9 |
| 2' 5" | 4.587 | 34.31 | 5' 3" | 21.65 | 161.9 |
| 2' 6" | 4.909 | 36.72 | 5' 6" | 23.76 | 177.7 |
| 2' 7" | 5.241 | 39.21 | 5' 9" | 25.97 | 194.3 |
| 2' 8" | 5.585 | 41.78 | 6' | 28.27 | 211.5 |
| 2' 9" | 5.940 | 44.43 | 6' 3" | 30.68 | 229.5 |
| 2' 10" | 6.305 | 47.16 | 6' 6" | 33.18 | 248.2 |
| 2' 11" | 6.681 | 49.98 | 6' 9" | 35.78 | 267.7 |
| 3' | 7.069 | 52.88 | 7' | 38.48 | 287.9 |
| 3' 1" | 7.467 | 55.86 | 7' 3" | 41.28 | 308.8 |
| 3' 2" | 7.876 | 58.92 | 7' 6" | 44.18 | 330.5 |
| 3' 3" | 8.296 | 62.06 | 7' 9" | 47.17 | 352.9 |

| Diameter | | Area in sq ft Cu ft per 1' of depth | U S gallons per 1' of depth | Diameter | | Area in sq ft Cu ft per 1' of depth | U S gallons per 1' of depth |
|----------|----|---|--------------------------------|----------|----|---|--------------------------------|
| 3' | 4" | 8.727 | 65.28 | 8' | | 50.27 | 376.0 |
| 3' | 5" | 9.168 | 68.58 | 8' | 3" | 53.46 | 399.9 |
| 3' | 6" | 9.621 | 71.97 | 8' | 6" | 56.75 | 424.5 |
| 3' | 7" | 10.08 | 75.44 | 8' | 9" | 60.13 | 449.8 |
| 9' | | 63.62 | 475.9 | 30' | | 706.9 | 5,288.0 |
| 9' | 3" | 67.20 | 502.7 | 31' | | 754.8 | 5,646.0 |
| 9' | 6" | 70.88 | 530.2 | 32' | | 804.3 | 6,016.0 |
| 9' | 9" | 74.66 | 558.5 | 33' | | 855.3 | 6,398.0 |
| 10' | | 78.54 | 587.5 | 34' | | 907.9 | 6,792.0 |
| 10' | 6" | 86.59 | 647.7 | 35' | | 962.1 | 7,197.0 |
| 11' | | 95.03 | 710.9 | 36' | | 1,018.0 | 7,616.0 |
| 11' | 6" | 103.9 | 777.0 | 37' | | 1,075.0 | 8,043.0 |
| 12' | | 113.1 | 846.0 | 38' | | 1,134.0 | 8,483.0 |
| 12' | 6" | 122.7 | 918.0 | 39' | | 1,195.0 | 8,940.0 |
| 13' | | 132.7 | 992.9 | 40' | | 1,257.0 | 9,404.0 |
| 13' | 6" | 143.1 | 1,071.0 | 41' | | 1,320.0 | 9,876.0 |
| 14' | | 153.9 | 1,152.0 | 42' | | 1,385.0 | 10,360.0 |
| 14' | 6" | 165.1 | 1,235.0 | 43' | | 1,452.0 | 10,860.0 |
| 15' | | 176.7 | 1,322.0 | 44' | | 1,521.0 | 11,370.0 |
| 15' | 6" | 188.7 | 1,412.0 | 45' | | 1,590.0 | 11,900.0 |
| 16' | | 201.1 | 1,504.0 | 46' | | 1,662.0 | 12,430.0 |
| 16' | 6" | 213.8 | 1,600.0 | 47' | | 1,735.0 | 12,980.0 |
| 17' | | 227.0 | 1,698.0 | 48' | | 1,810.0 | 13,540.0 |
| 17' | 6" | 240.5 | 1,799.0 | 49' | | 1,886.0 | 14,110.0 |
| 18' | | 254.5 | 1,904.0 | 50' | | 1,964.0 | 14,690.0 |
| 18' | 6" | 268.8 | 2,011.0 | 52' | | 2,124.0 | 15,890.0 |
| 19' | | 283.5 | 2,121.0 | 54' | | 2,290.0 | 17,130.0 |
| 19' | 6" | 298.6 | 2,234.0 | 56' | | 2,463.0 | 18,420.0 |
| 20' | | 314.2 | 2,350.0 | 58' | | 2,642.0 | 19,760.0 |
| 20' | 6" | 330.1 | 2,469.0 | 60' | | 2,827.0 | 21,150.0 |
| 21' | | 346.4 | 2,591.0 | 62' | | 3,019.0 | 22,380.0 |
| 21' | 6" | 363.1 | 2,716.0 | 64' | | 3,217.0 | 24,060.0 |
| 22' | | 380.1 | 2,844.0 | 66' | | 3,421.0 | 25,590.0 |
| 22' | 6" | 397.6 | 2,974.0 | 68' | | 3,632.0 | 27,170.0 |
| 23' | | 415.5 | 3,108.0 | 70' | | 3,488.0 | 28,790.0 |
| 23' | 6" | 433.7 | 3,245.0 | 72' | | 4,072.0 | 30,450.0 |
| 24' | | 452.4 | 3,384.0 | 74' | | 4,301.0 | 32,170.0 |
| 24' | 6" | 471.4 | 3,527.0 | 76' | | 4,536.0 | 33,930.0 |
| 25' | | 490.9 | 3,672.0 | 78' | | 4,778.0 | 35,740.0 |
| 25' | 6" | 510.7 | 3,820.0 | 80' | | 5,027.0 | 37,600.0 |
| 26' | | 530.9 | 3,972.0 | 82' | | 5,281.0 | 39,500.0 |
| 26' | 6" | 551.5 | 4,126.0 | 84' | | 5,542.0 | 41,450.0 |
| 27' | | 572.6 | 4,283.0 | 86' | | 5,809.0 | 43,450.0 |
| 27' | 6" | 594.0 | 4,443.0 | 88' | | 6,082.0 | 45,490.0 |
| 28' | | 615.8 | 4,606.0 | 90' | | 6,362.0 | 47,590.0 |
| 28' | 6" | 637.9 | 4,772.0 | 92' | | 6,648.0 | 49,720.0 |
| 29' | | 660.5 | 4,941.0 | 94' | | 6,940.0 | 51,920.0 |
| 29' | 6" | 683.5 | 5,113.0 | 96' | | 7,238.0 | 54,140.0 |
| | | | | 98' | | 7,543.0 | 56,420.0 |
| | | | | 100' | | 7,854.0 | 58,750.0 |

APPENDIX II

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APPENDIX III

GLOSSARY

- Acid.* Sour-tasting (vinegarlike) substance. Common acids are sulfuric, nitric, hydrochloric (muriatic), carbonic, and acetic.
- Adsorption.* Removal of gases or liquids from water by adhesion to the surface of a solid, such as activated carbon. This process should not be confused with absorption in which a gas or liquid penetrates the interior of a solid, such as water being absorbed by a sponge.
- Aeration.* Spraying or otherwise exposing water to air to reduce objectionable tastes or odors. The same results are obtained by bubbling air through the water.
- Algae.* Microscopic plants some of which form a green scum on water and which may give the water unpleasant tastes and odors.
- Alkalinity.* The condition of water containing dissolved alkaline substances, like lye.
- Alkaloid.* An organic substance having alkaline properties and usually detrimental to health when present in drinking water.
- Backwashing.* The washing of a filter by reversing the flow of water through it to remove accumulated impurities.
- Bacteria.* A large group of one-celled microorganisms. Some are disease-producing.
- Bone oil.* Oily liquid obtained from heating bones. When added to reservoirs and other containers, it gives the water a nauseating taste and odor.
- Blister agent.* A chemical warfare agent which burns or blisters the skin or internal tissues of the body. Mustard and lewisite are the common blister agents.
- Blowdown.* The water removed from an evaporator or boiler to prevent the excessive concentration of dissolved solids and the consequent formation of scale.
- Btu.* Abbreviation of *British Thermal Unit*, a measure of work or energy; the amount of heat required to raise the temperature of 1 pound of water 1° F.
- Calcium hypochlorite.* A chemical compound in powdery or granu-

lar form containing chlorine used to disinfect water by chlorination.

Carbon dioxide. A gas composed of carbon and oxygen. When dissolved in water, it forms carbonic acid which has a corrosive effect on many metals.

Chemical warfare agent. Chemical used as a weapon. Poison gases, irritant gases, incendiaries, and screening smokes are chemical warfare agents.

Chlorination. The disinfection (destruction of disease-producing microorganisms) of water by adding chlorine in the form of a gas or calcium hypochlorite.

Chlorine. A greenish yellow gas which destroys certain microorganisms in water.

Chlorine demand. The amount of the chlorine dosage used by the chlorine-consuming substances in the water; the difference between chlorine dosage and residual chlorine.

Coagulant. Chemical used in the coagulation of water.

Coagulation. The formation of masses of gelatinous precipitates in water by adding alum or other suitable chemicals (see flocculation) for clarifying water.

Comparator. Apparatus for matching the color of a water sample to which a dye has been added with permanent color standards. It is used to determine pH and residual-chlorine values.

Compression. Act of forcing a gas or vapor to occupy a smaller volume; this increases its pressure and temperature.

Compressor. Mechanical device for compressing a gas or vapor.

Condensate. Product of condensation; distillate.

Condensation. Act of changing vapor to liquid by removing its latent heat. (See distillation.)

Condenser. Device for removing latent heat from vapor.

Cone of influence. Conical depression in ground-water table caused by water flowing into a well.

Contamination. Water is contaminated when unsuitable for consumption because of the presence of disease-producing bacteria or other harmful substances.

Cooler. Device for lowering the temperature of a fluid.

Cross connection. Improper arrangement of pipes which permits impure water to mix with and contaminate or pollute the public (potable) water supply.

Cyst. Shell or sac surrounding certain amoeba, which makes them resistant to ordinary chlorination.

Diatomite. The processed skeletal remains of tiny algae, called diatoms, found in marine deposits which have been lifted above sea level; the filtering medium in diatomite filters. It is also called

diatomaceous silica, filteraid, and diatomaceous earth.

Disease organisms. Any microorganism, such as bacteria or protozoa, which impairs the health of troops.

Disease. Any impairment of health which lowers the efficiency of troops; usually caused by microorganisms.

Disinfection. Process of destroying disease organisms. Water for troops is disinfected by chlorination.

Distillation. Process of changing water into water vapor, separating the water vapor from the water, and changing the water vapor back into water. It is used to separate water from dissolved solids, such as salt.

Distillate. Product of distillation; also called condensate and distilled water.

Dosage. The definite quantity of chemical necessary to obtain a desired result, as the amount of calcium hypochlorite necessary to disinfect water.

Draw-down. Difference between water level in a well before pumping and level during pumping.

Dry point. A water distributing point to which treated water is hauled.

Effect. One evaporator of a series of connected evaporators of a distillation unit.

Endamoeba histolytica. The protozoa which causes amoebic dysentery.

Evaporator. Device for changing water to steam and for separating the steam from the water; an effect.

Expedient. Any suitable improvised means of accomplishing a desired end.

Filter. Device for separating suspended solids from water by passage through a porous medium such as sand or diatomite.

Filteraid. A filtering medium, especially diatomite.

Filtration. Process of filtering.

Fish oil. Oil obtained by pressing or steaming fish; gives water a disagreeable taste and odor.

Floc. Jellylike masses formed in water by flocculation.

Flocculation. The collection of small particles of floc in water by gentle agitation into large masses which attract dirt and disease organisms while settling. (See coagulation.)

Friction. In pipes, the resistance to flow of water.

Gas. An airlike fluid having neither definite shape nor volume, but which tends to expand indefinitely.

Germ. Any disease-producing microorganism, a pathogen.

Grains per gallon. Unit expressing the ratio of chemicals in, or to be added to, a gallon of water. One pound equals 7,000 grains,

hence 1 grain per gallon equals 143 pounds per million gallons, or roughly, $\frac{1}{8}$ pound per 1,000 gallons.

Ground water. Water in underground deposits which can be recovered by wells or springs.

Halazone. Individual water purification tablets containing an organic chloramine for disinfecting water.

Head. Pressure exerted by a column of liquid. A head of 2.31 feet of water exerts a pressure of 1 pound per square inch (psi).

Heat exchanger. Device for transferring heat from a substance at higher temperature to a substance at a lower temperature without physical contact between the two substances.

Horsepower. Unit of power equal to 550 foot-pound per second.

Impurity. Any substance which makes water unfit for use; contamination and pollution.

Indicator. Any water-soluble dye which changes color with variations in pH or chlorine content of the water.

Installation. Arrangement of equipment to treat and distribute water; a water point.

Intake. The device through which water is taken from the source.

Jar Test. Small-scale coagulation test; test for determining coagulant dosage and optimum pH of water to be treated.

Latent heat. Heat involved when a substance changes from one state to another, as water to steam. This heat is not evidenced as a change in temperature.

Layout. Arrangement of water treating or distributing equipment.

Lyster bag. Fabric bag in which water can be chlorinated. Holds 36 gallons.

Medium (Filter). Porous substance capable of passing fluids and of retaining solids; diatomite, sand, and similar substances.

Microorganism. Tiny animallike growths that cannot be seen without a microscope.

Mobile unit. Water purification unit, truck-mounted.

Odor. Any objectionable smell in water.

Oil-fired. Method of heating water in distillation equipment with an oil burner; distinct from thermocompression.

Optimum pH. The pH at which best floc formation occurs; usually the floc forms and settles fastest at this point.

Oxygen. The chemical element necessary for combustion; in its pure state it exists as a gas. About one-fifth of the air is oxygen.

Ozone. An unstable form of oxygen.

Palatable. Agreeable or pleasing to the taste; not to be confused with potable. A palatable water may not be potable, but a potable water should be palatable.

Parts per million (ppm). Ratio denoting the number of units of a

substance in one million units of water by weight.

pH value. A measure of the strength of acidity or alkalinity of substances measured on a scale ranging from 0 for maximum acidity to 14 for maximum alkalinity.

Poison. Any agent which may produce injurious or deadly chemical effects.

Pollution. Water is polluted when it contains substances of such quantity and character as to make its appearance, taste, or odor objectionable.

Portable unit. Water purification unit, portable.

Potable. Drinkable; water is potable when it is safe and also pleasant to drink.

ppm. Abbreviation for parts per million.

Precipitate. A solid substance separated from a solution by some chemical or physical change.

Pressure. A force in the nature of a thrust or push distributed over a unit surface.

Pretreatment. Partial clarification of water by sedimentation and coagulation before filtration.

Priming. To put pumps into operation by adding water to the casing; to carry fine droplets of water out of the evaporator with the steam.

Protozoa. Simplest form of animal; body consists of one cell; reproduces by division. The protozoa most dangerous to water supply is "Endamoeba histolytica," cause of amoebic dysentery.

psi. Pounds per square inch.

Purification. Treatment of water to make it potable.

Residual chlorine. The amount of chlorine remaining in water after the original chlorine dosage has reacted with the chlorine-consuming substances in the water for a certain time (in the Army for 10 minutes); the difference between chlorine dosage and chlorine demand.

Road net. System of interconnecting roads.

Salt. Any chemical compound which results from reaction between an acid and a base (alkali); most common example is sodium chloride.

Scale. Hard, insoluble layers of certain alkaline minerals deposited on hot metal parts of boilers and evaporators by hard water. Scale reduces heat exchange efficiency.

Schistosome. Blood fluke, worm parasite found in some parts of the world, the larval stage of which is water-borne and enters the human body through the skin or mouth causing schistosomiasis.

Sedimentation. Process of removing suspended solids from water by gravity or settling.

- Seizing.* Inability of a rotating part of a device or machine to turn over in its stator or bearing because of abnormal friction.
- Septum.* Porous hollow cylindrical filter-cake support used in diatomite filters.
- Set.* An issued assembly of related equipment necessary to accomplish a definite objective.
- Sewage.* Refuse, liquids or matter carried off in pipes or conduits.
- Silt.* Sedimentary material suspended in water; technically, material whose particle size ranges between that of sand and clay.
- Slurry.* Thin, watery paste.
- Soda ash.* Sodium carbonate (Na_2SO_3).
- Spore.* Unicellular reproductive body produced by plants and protozoa for surviving under unfavorable conditions.
- Springs.* An issue of water from the earth.
- Standpipe.* In municipal water systems, a high vertical pipe used as an intermediate distributing reservoir to obtain uniform pressure; at water points, a vertical pipe for distributing water under pressure.
- Steam.* Water vapor.
- Steam generator.* Device for making steam; an evaporator, a boiler.
- Surface water.* Water on the earth's surface, such as rivers, lakes, and ponds.
- Thermal cracking.* Method of removing scale from tubes by rapid heating and cooling.
- Thermocompression.* Method of distilling water by compressing steam.
- Turbidimeter.* Device for measuring the amount of suspended solids in water.
- Vaporize.* To change from liquid to vapor, as water to steam, by adding heat.
- Unit.* 1. Any quantity adopted as a standard of measurement. 2. Any integrated whole, as a portable unit.
- Up-draw.* Rise of salty ground water underlying a layer of fresh water. Occurs when the fresh water is pumped.
- Water-borne.* Conveyed by water. Used when referring to the mechanical transmission of organisms from their source to the human system of water.
- Watercycle.* Natural process of evaporation, rainfall and runoff.
- Water point.* Installation of equipment for treating and distributing water to troops.
- Water vapor.* Steam; water which has changed to a gaseous state.
- Weir.* A device for determining the quantity of flowing water by measuring the depth of water flowing over a fixed notch.
- Well.* A ground-water intake penetrating to the ground-water table.

APPENDIX IV

FLOW DIAGRAMS

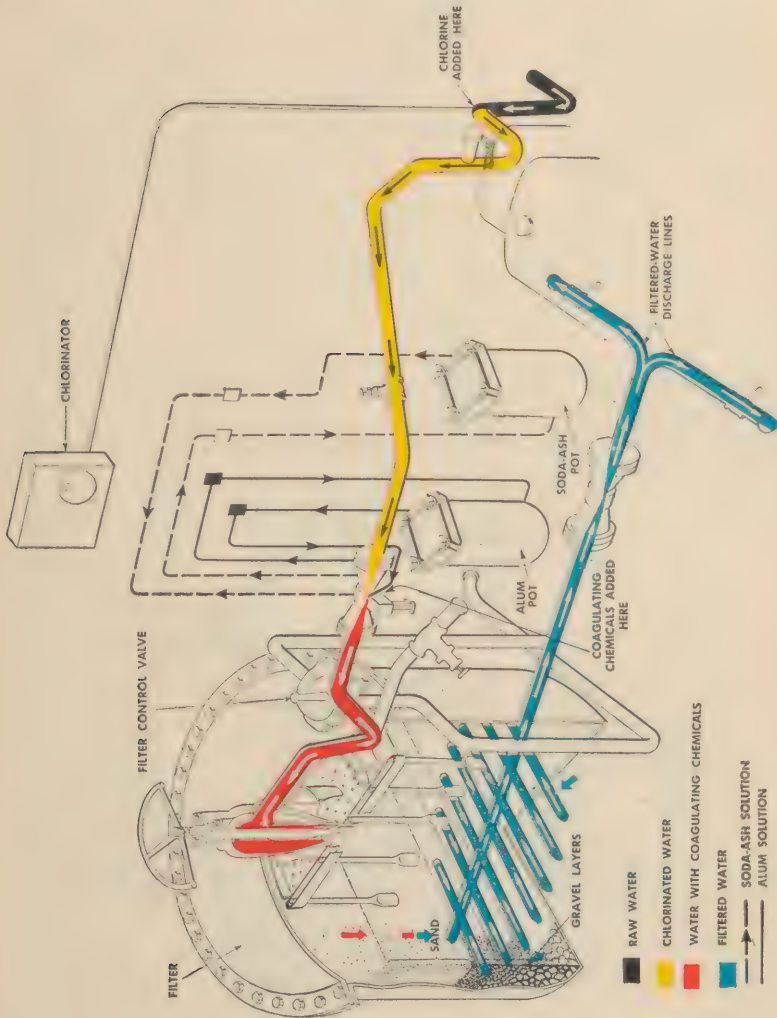


Plate I. Flow diagram of water during production of filtered water in water purification unit truck-mounted. (mobile). (See par. 65a(1).)

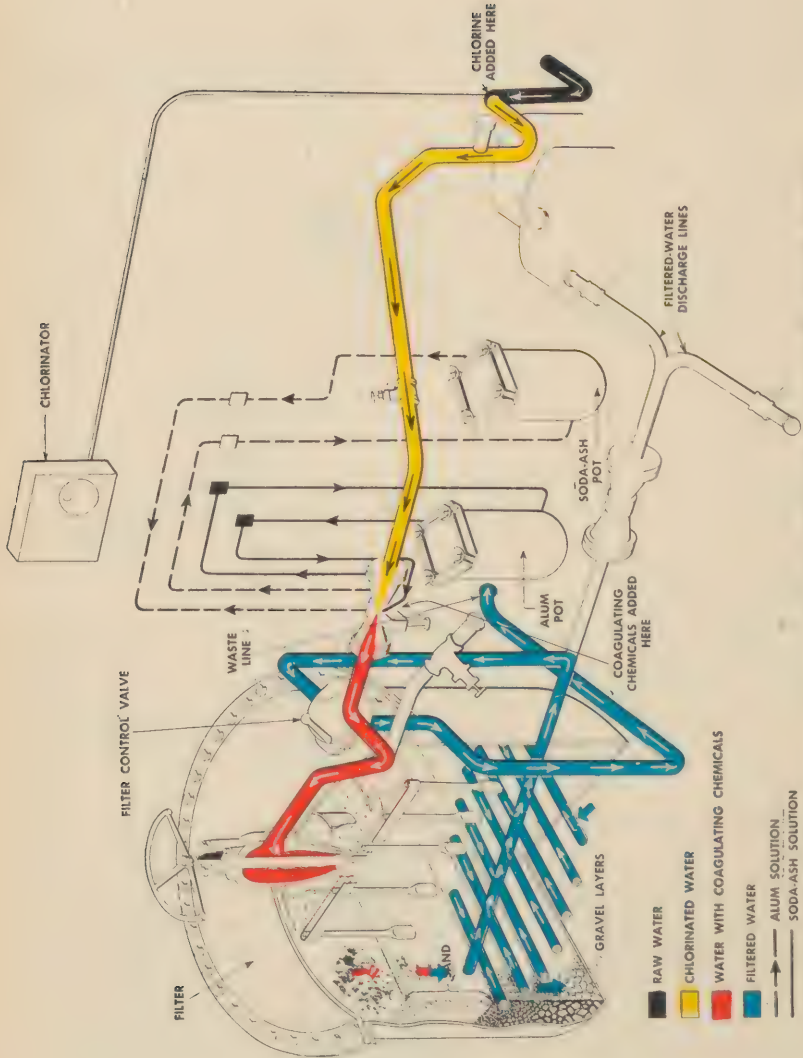


Plate II. Flow diagram of water during filtering to waste in water purification unit, truck-mounted (mobile). (See par. 65a(2).)

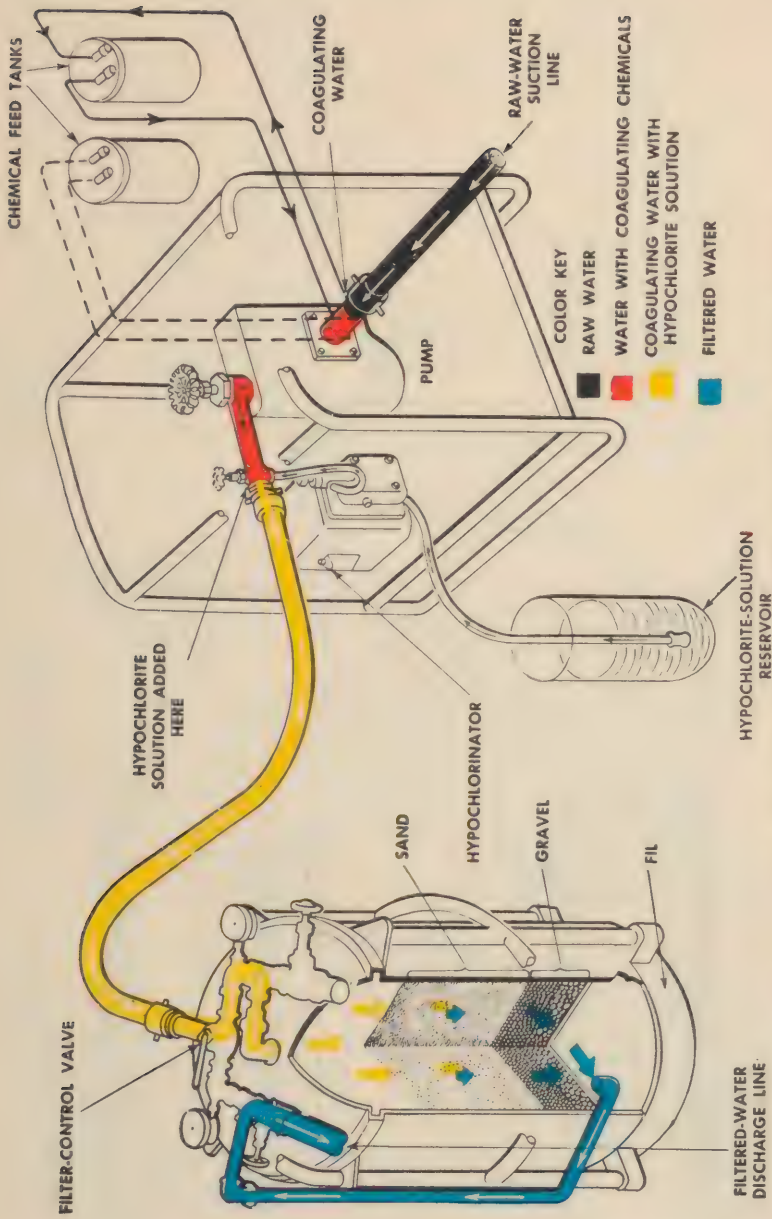


Plate III. Flow diagram of water during production of filtered water in water purification unit, portable. (See par. 71a(1).

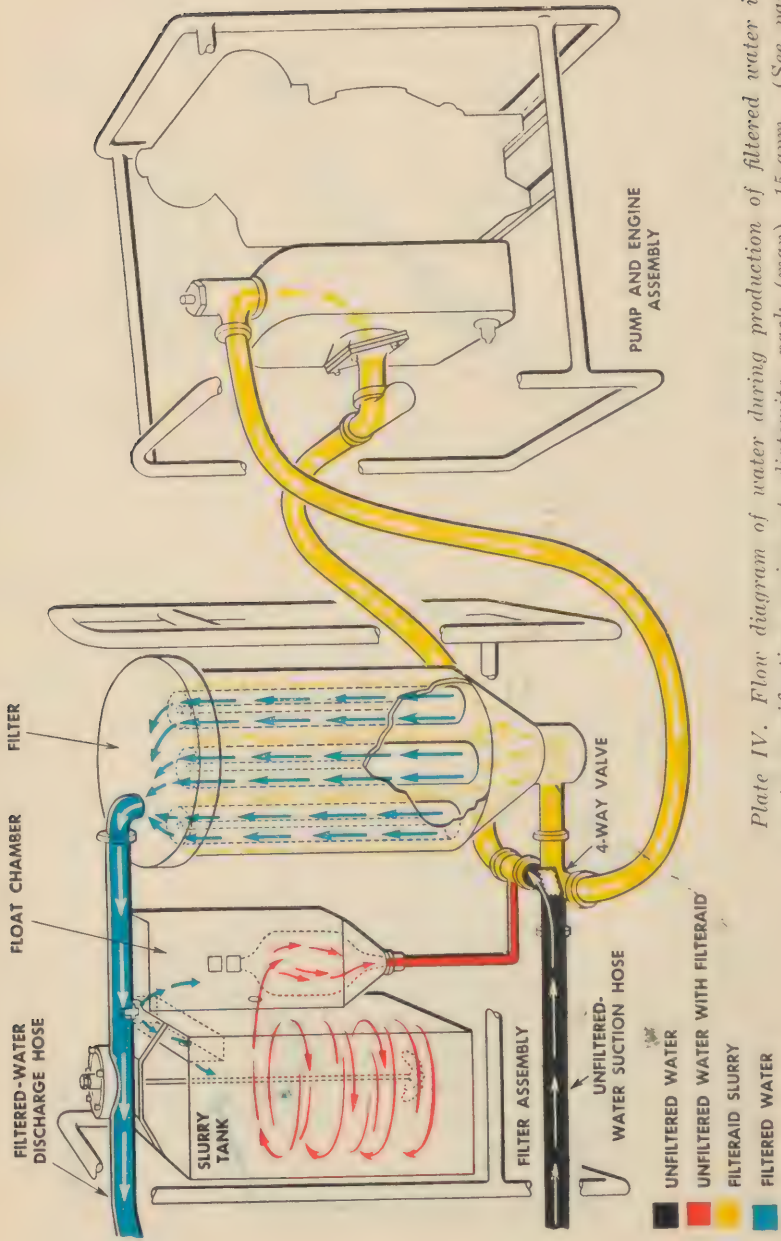


Plate IV. Flow diagram of water during production of filtered water in water purification equipment, diatomite, pack (man), 15-gpm. (See par. 76a(1).)

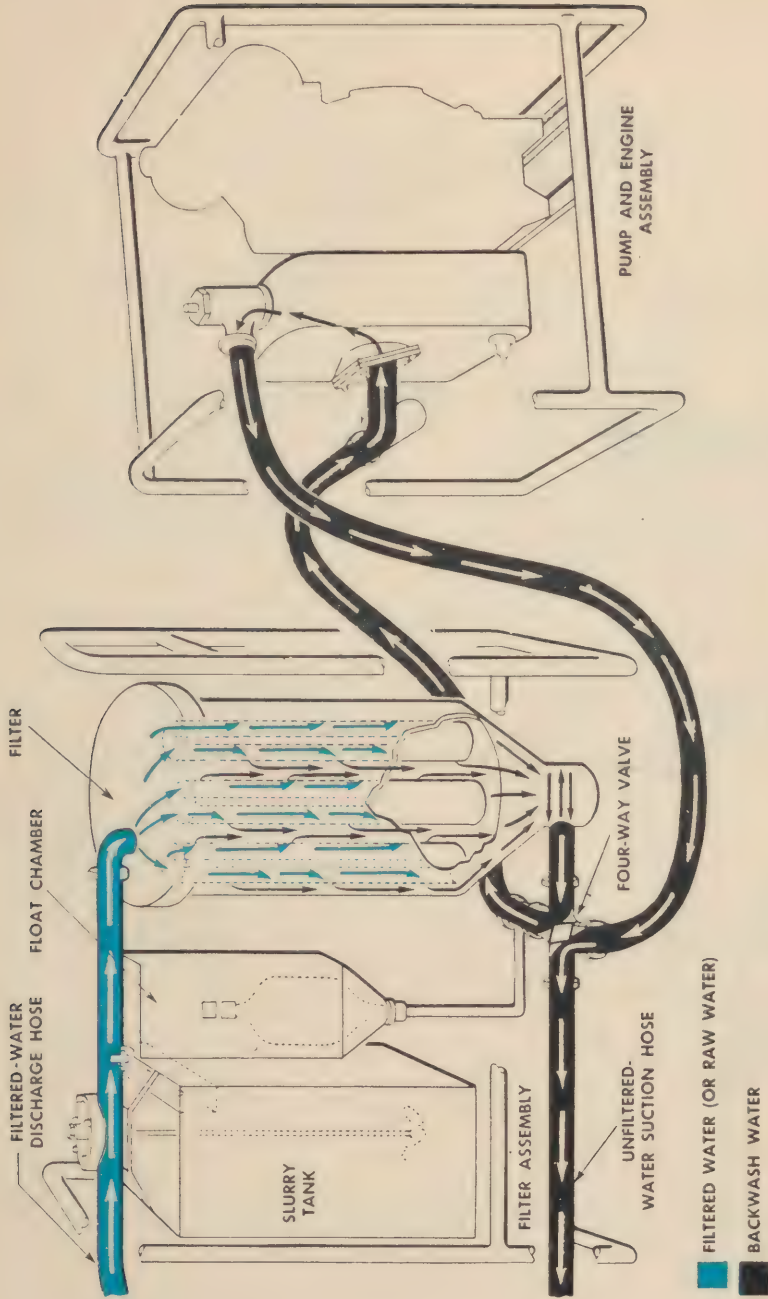


Plate V. Flow diagram of water during backwashing of water purification equipment, diatomite, pack (man), 15-gpm. (See par. 76a(2).)

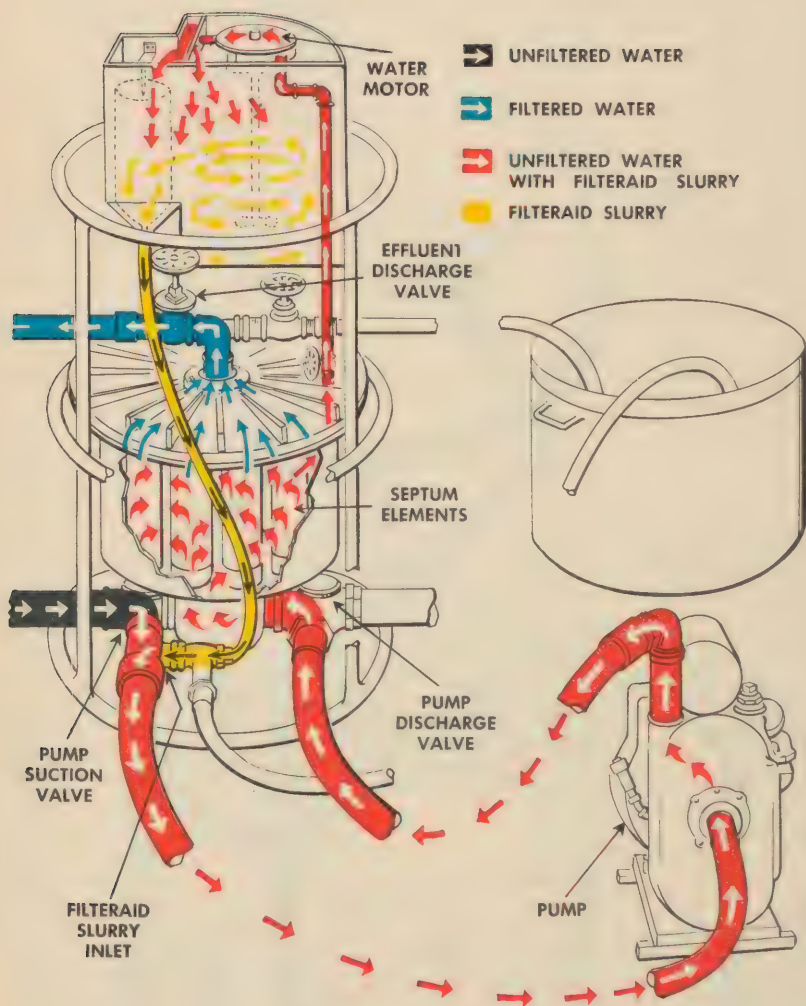


Plate VI. Flow diagram of water during production of filtered water in water purification equipment, diatomite, portable, 50-gpm. (See par. 82a(1).)

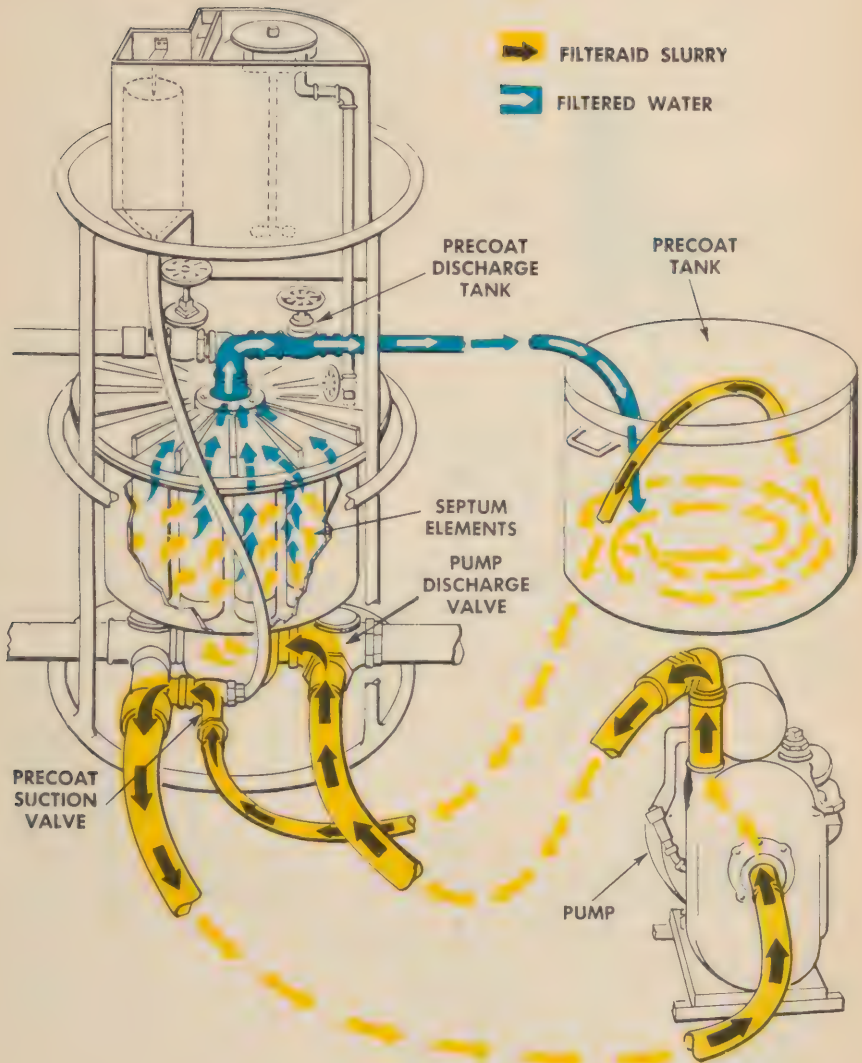


Plate VII. Flow diagram of water during precoat of water purification equipment, diatomite, portable, 50-gpm. (See par. 82a(3).)

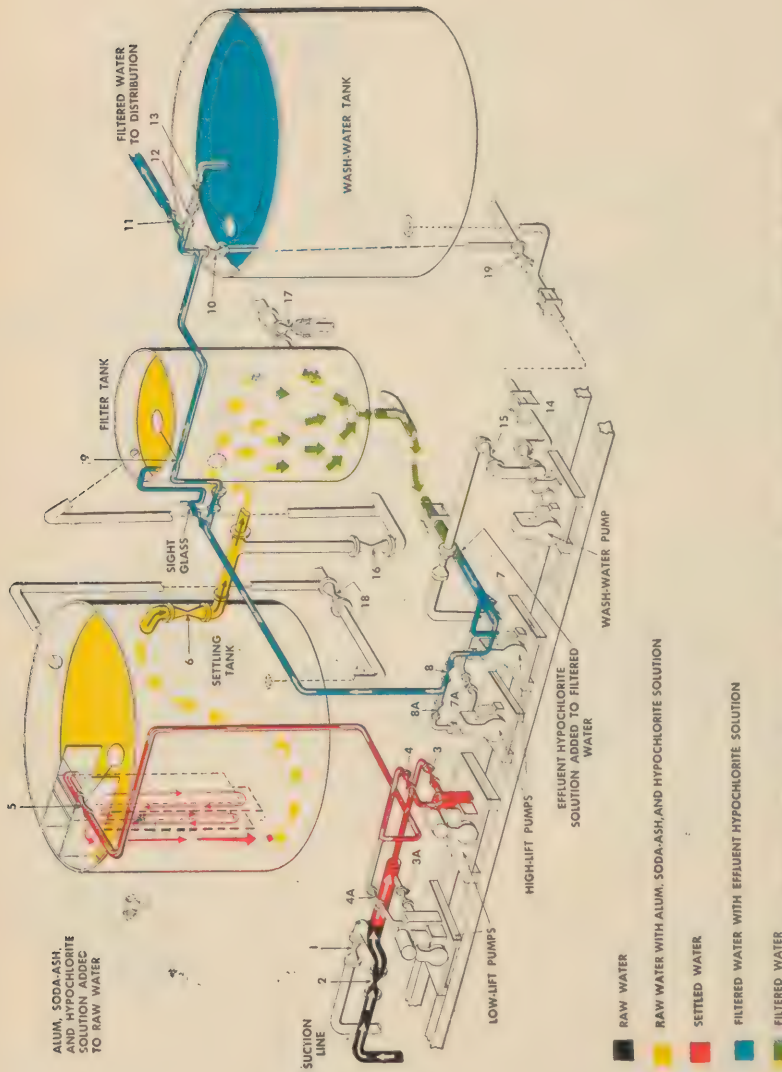


Plate VIII. Flow diagram of water during production of filtered water in water purification unit, stationary (knockdown-type). (See par. 88a(1).)

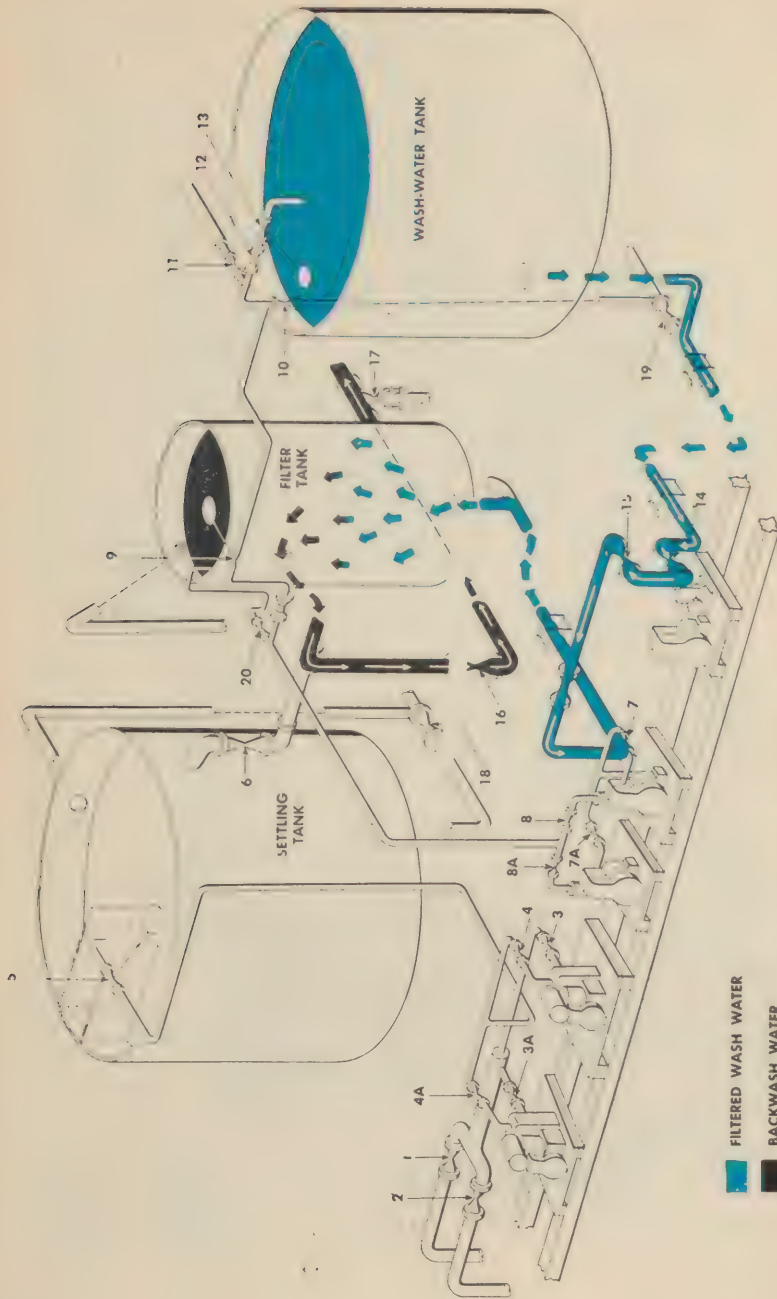


Plate IX. Flow diagram of water during backwashing of water purification unit, stationary (knockdown-type). (See par. 88a(2).)

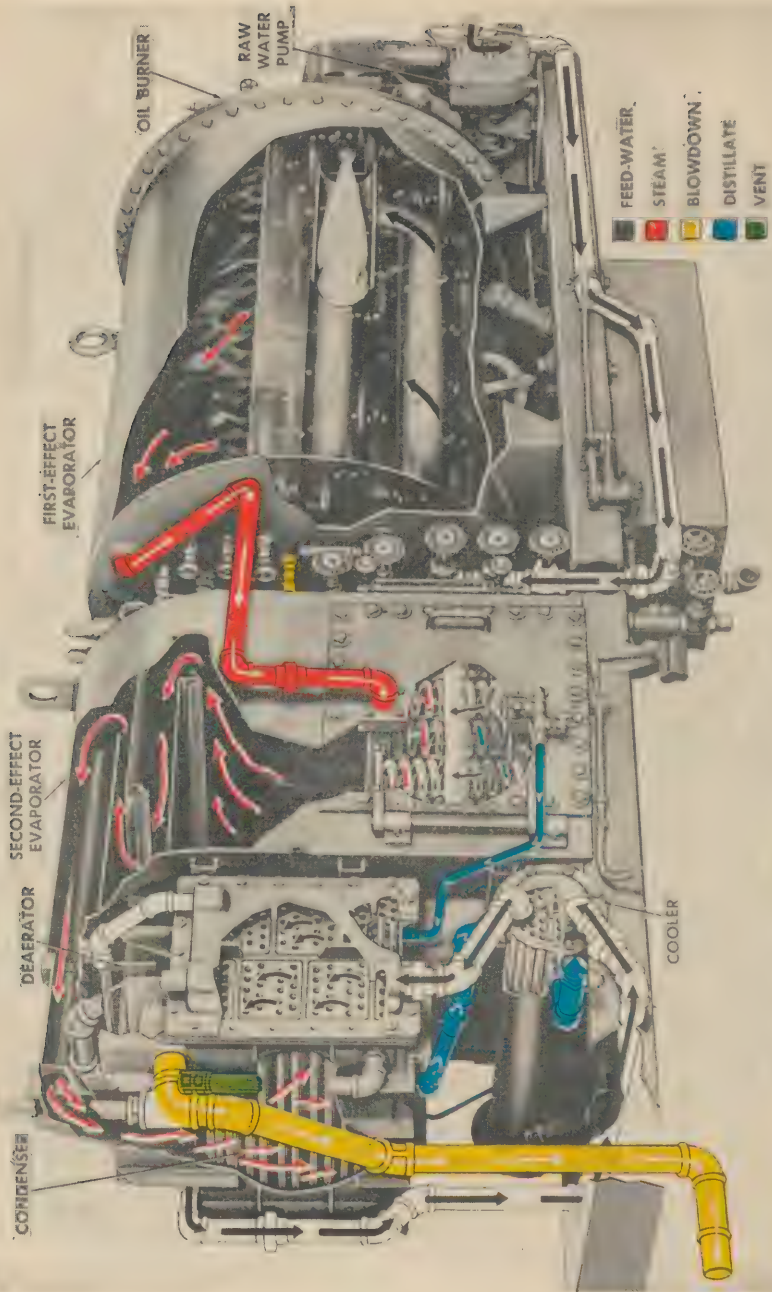


Plate X. Cutaway view showing flow of water in 2,000-gpd double-effect distillation unit. (See par. 118.)

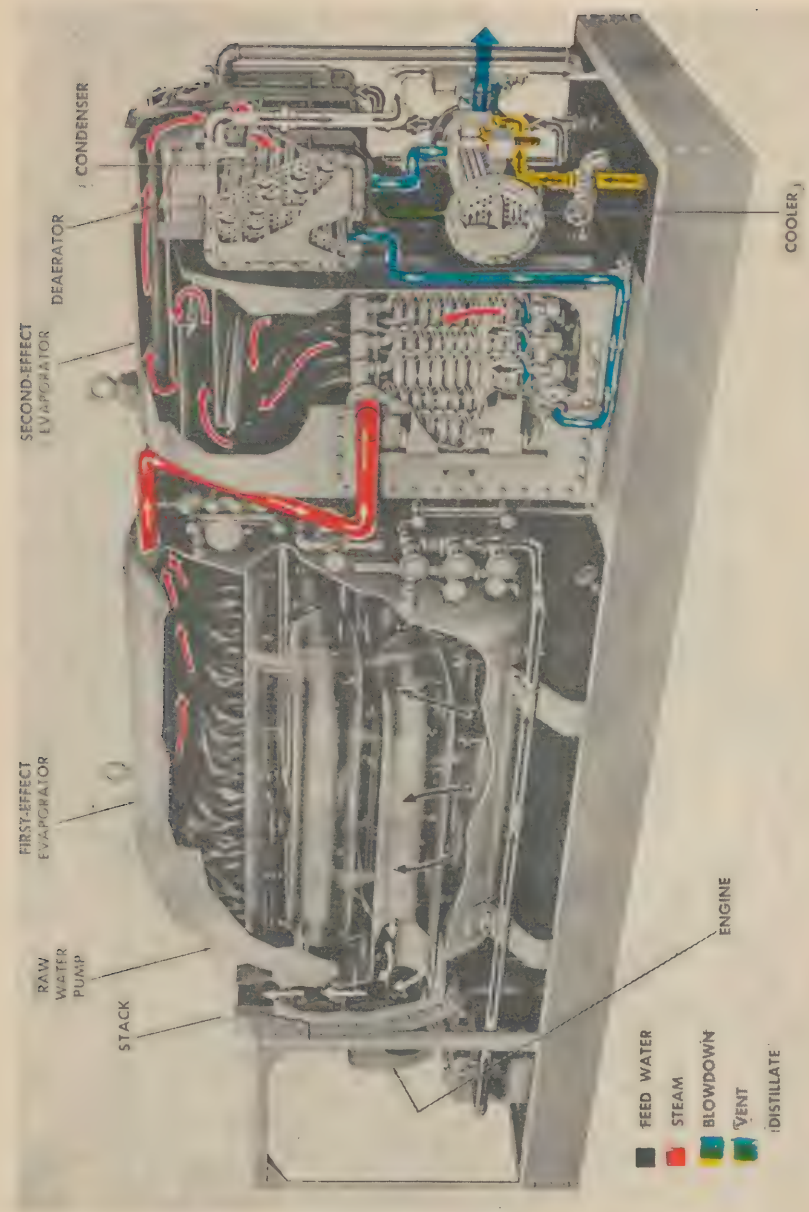


Plate XI. Cutaway view showing flow through 5,000-gpd double-effect distillation unit. (See par. 118.)

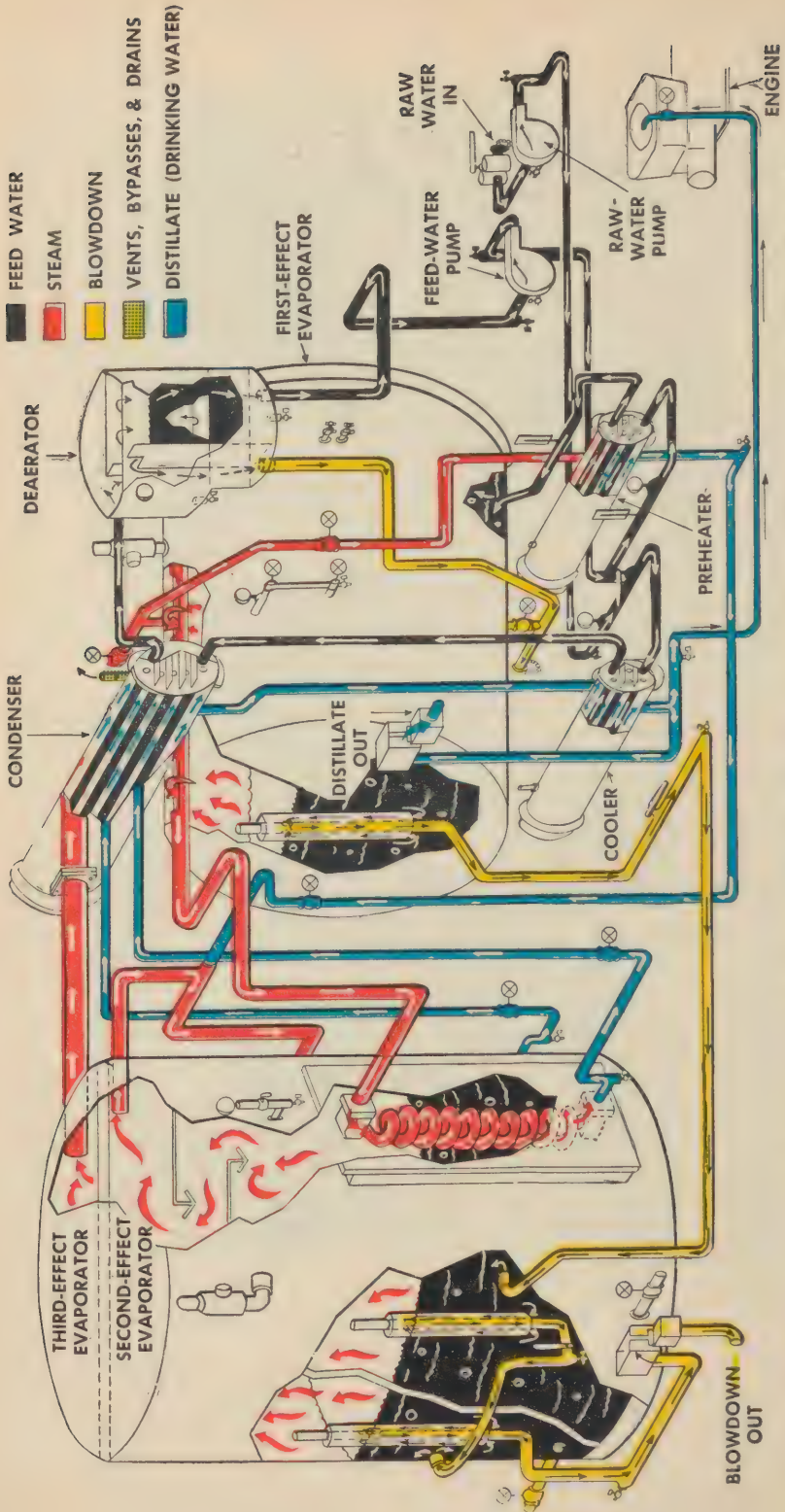


Plate XII. Cutaway view showing flow through 2,500-gpd triple-effect oil-fired distillation unit. (See par. 122.)

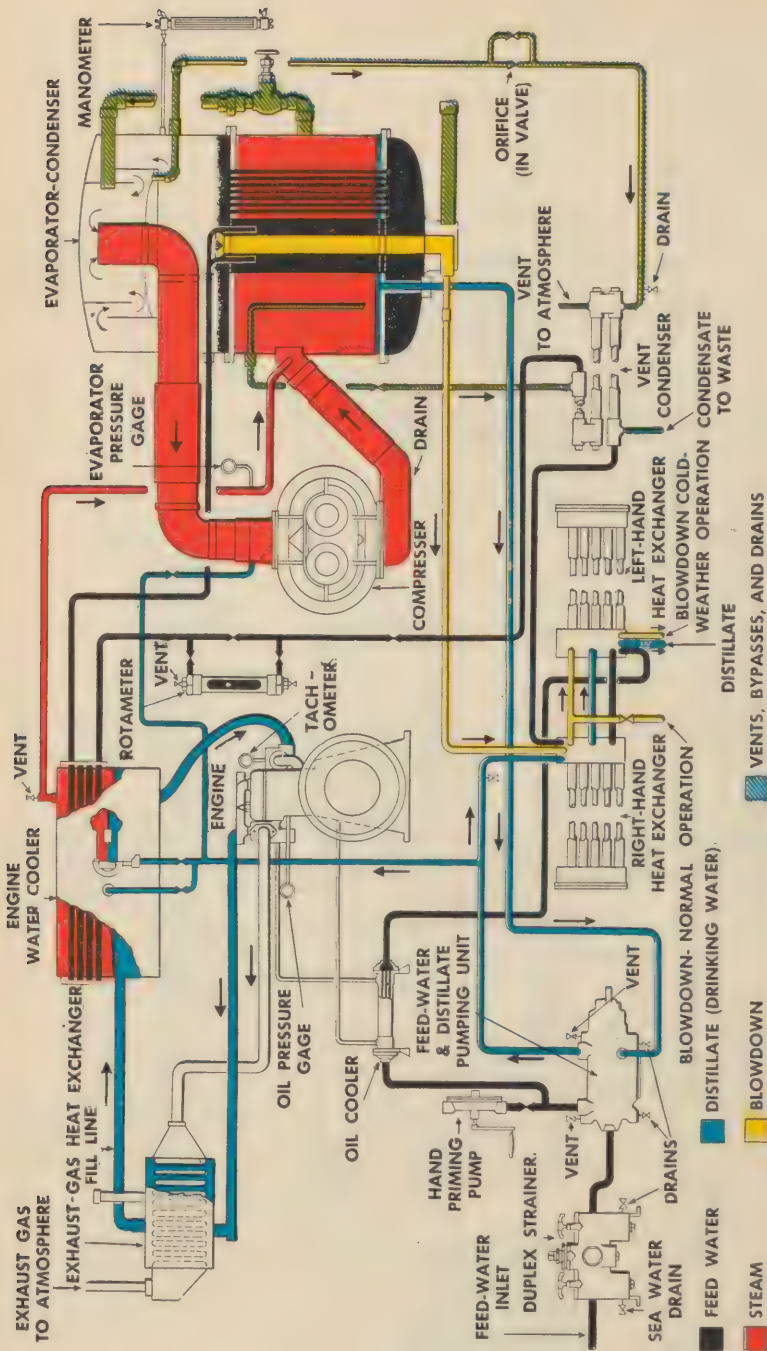


Plate XIV. Flow diagram of 3,000-gpd thermocompression distillation unit.
(See par. 127a.)

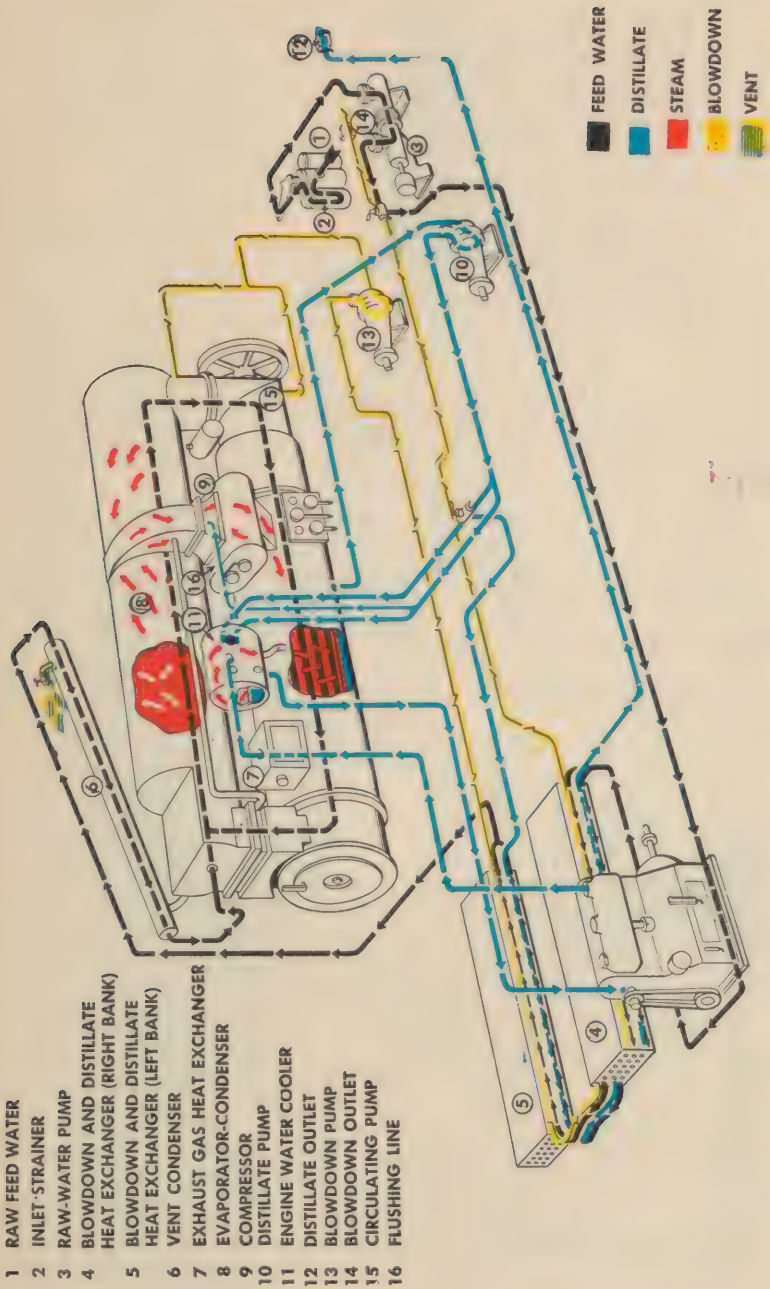


Plate XV. Flow diagram of 3,000-gpd thermocompression distillation unit (Cleaver-Brooks). (See par. 128a.)

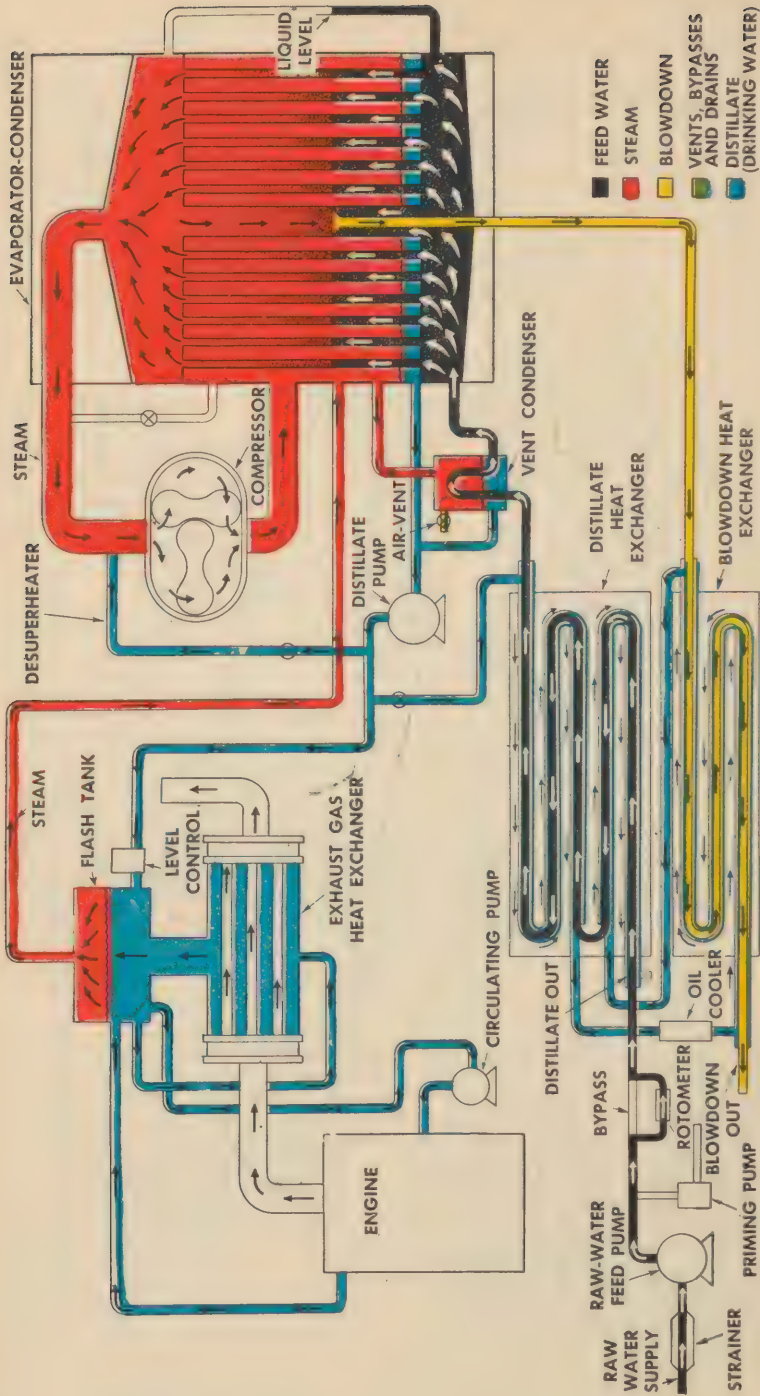


Plate XVI. Flow diagram of 6,000-gpd thermocompression distillation unit.
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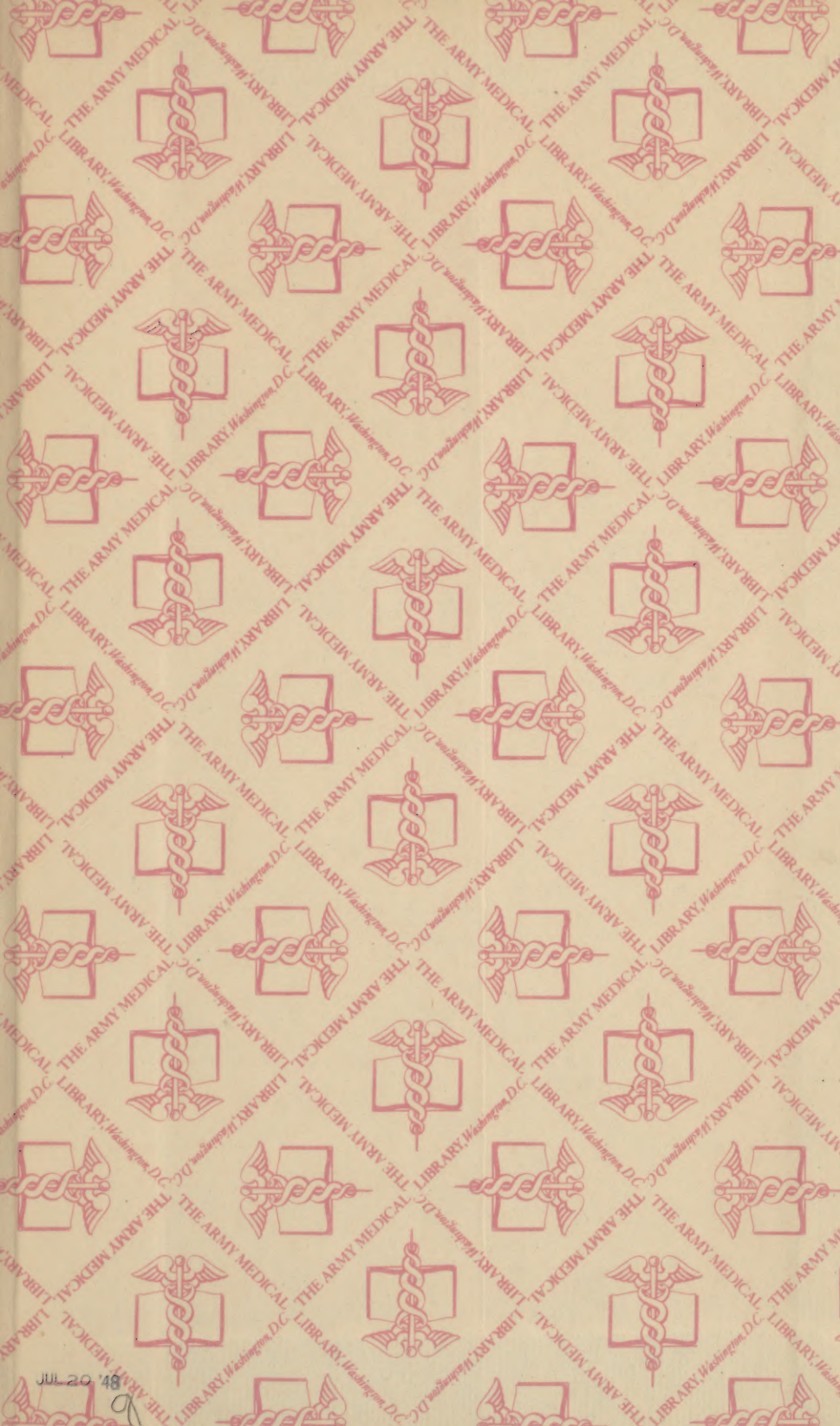
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